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The Meteoritic Origin of Lunar Structures

By RALPH B. BALDWIN

On the face of the Moon is the record of its past history. Each marking tells a story of one phase, but it is only when we begin to seek possible modes of production of the various lunar features and to correlate them that a clear picture of the actual processes involved becomes possible.

Various theories which attempt to explain the lunar markings have been formulated. Although some of them are equally satisfactory in accounting for certain types of features, it is only when markings are found which could not have been produced by a suggested process that a choice can be made between various modes of origin.

Such markings are present on the lunar surface. They are of several kinds, but all of them combine to indicate that they were formed as a result of a single, tremendous initial action.

In a recently published description[1] the most prominent markings of this type have been labelled as "splash craters."

In Mare Vaporum is a series of at least a dozen elongated craters, from thirty to fifty miles in length and perhaps ten miles broad. They are nearly, but not exactly parallel and their major axes projected in the convergent direction all pass close to the center of Mare Imbrium. They could only have been produced by the almost tangential impacts of large masses of flying matter.

Second is the strange appearance of the southern and southeastern rim of Mare Serenitatis. It looks very much like a curved ridge of sand on which a jet of water has been turned. Apparently it has been extensively mutilated by flying material which also came from the direction of the central region of Mare Imbrium.

Third is a series of grooves approximately three miles broad and from twenty to seventy miles long. They are found in the region of Ptolemaeus, Alphonsus, Hipparchus, and Albategnius and all converge northward toward the central region of Mare Imbrium. The grooves, which may be regarded as more elongated versions of the Mare Vaporum splash craters, cut indiscriminately through crater walls, bottoms, and spaces between the craters. Consequently they are of more recent formation than the more usual round craters.

The fourth type is composed of a group of ridges in the section of the Moon northeast of Ptolemaeus and extending beyond Copernicus. The ridges are also radial to Mare Imbrium. They are roughly twenty miles long and three miles wide.

There is thus a variety of lunar surface features which are oriented toward the central section of Mare Imbrium. All of them lie within 800 miles of this sea and most of them are in a region shaped like a great fan whose vertex is in Mare Imbrium and whose edges form an angle of 150°.

The existence of so many obviously associated markings is not a chance occurrence. They were formed because of something that happened in the center of Mare Imbrium. This must have been a tremendous explosion which showered debris over the moonscape. Low velocity ejections formed the nearby ridges, masses moving with higher velocities gouged out the more distant splash craters, while the grooves were cut at great distances by still faster moving bodies.

A fifth type of associated lunar feature includes the maria. They are huge solidified lava flows with Mare Imbrium in a nearly central position. Their importance in helping to explain the sequence of events lies in the fact that the once liquid lava in spreading to its present size overflowed numerous craters. Many of these partially drowned craters appear near the edges of the lava sheets Mare Nubium and Oceanus Procellarum.

It is seen that most of the circular craters, as distinguished from the splash craters, were formed before the maria. The latter thus could have been formed in association with the explosion previously mentioned.

A sixth type of marking is exemplified several times in Mare Serenitatis and Mare Tranquillitatis. The features are great wrinkle-like ridges, hundreds of miles long, which mar the otherwise smooth surface of the lava flows. They indicate that the maria were really full of liquid rock at one time and that pressure ridges developed as the lava cooled and solidified.

These are the observed facts. They point toward a specific sequence of processes which formed many of the lunar structures.

In the following pages is a description of a portion of the probable history of the Moon. A more nearly complete description will be found in the August, 1942, issue of POPULAR ASTRONOMY.

Inferences are drawn from observation and theory, and a series of operations is suggested as adequate to explain the observed features. Much of the numerical work is, of necessity, very rough, but it is believed that the fundamental thesis is established.

It is generally accepted that the Moon and Earth were once one body which later divided into two.[2] At the time of fission numerous masses were broken loose and many of them did not immediately coalesce with either major component, but began swinging around the Earth in more or less eccentric orbits.

Jeffreys[3] has stated that the Earth became liquid within 5,000 years

of its assumed gaseous start, and that it had a solid crust within 15,000 years.

Because of the magnitude of the forces involved, the Moon was probably in a liquid state and several thousand degrees hot when it separated from the Earth. It would, nevertheless, have cooled even more quickly than the Earth previously did to the point where a crust could develop.

The solid surface of the Moon thus came into being so soon after fission that the Moon and Earth were still sweeping up the meteoritic by-products of the separation. These smaller masses, in plunging to the lunar surface with a minimum velocity of one and one-half miles per second, were the causes of the craters. The latter were literally blasted out of the smooth, but rocky, primal surface.

In this view the craters should be distributed nearly evenly in all sections of the Moon. The fact that they are not observed in uniform numbers in the various parts of the lunar surface does not invalidate the above suggestion, as will be explained later.

It is seen by a mere glance at a photograph of the Moon that the crater-forming falls occurred over a considerable period of time as many craters have been more or less completely obliterated by craters formed later.

The number of craters varies tremendously with their size. Those of smallest diameters are most numerous and as the size increases the total number in each division decreases.

This may be interpreted as meaning that the smaller meteoritic particles were the most numerous. However, included among the millions of tiny masses were a few gigantic ones whose diameters were of the same order as those of the asteroids.

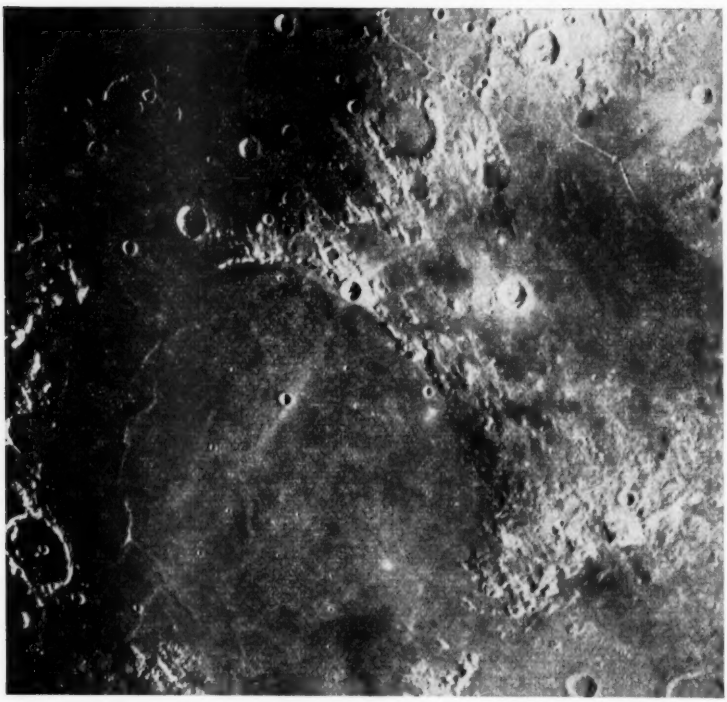
Spread over the surface of the Moon are the records of the impacts of at least four of these supergiant meteorites. In order of increasing diameter these oversize craters are Sinus Iridum, Mare Crisium, Mare Serenitatis, and Mare Imbrium. Each is a tremendous, nearly circular plain surrounded by high mountains. These mountains are comparable in size to those on Earth, but must have been formed in an entirely different manner. No circular mountain ranges are found on the Earth, while on the Moon it is the usual form, an expanded version of the smaller crater walls. Probably the Moon cooled too rapidly to allow the terrestrial form of tectonic forces to operate.

The reasons for identifying Mare Imbrium and its bordering mountain ranges, the Alps, Caucasus, and Apennines, as a crater are these. Briefly, the size of the sea is too great to admit its being a volcano and the presence of numerous elongated splash craters, grooves, and ridges which are oriented toward the center of Mare Imbrium indicates that a tremendous explosion took place there, and that these radial markings were produced by flying debris. The energies released are adequately

explained only as the result of the collision of a gigantic meteor and the Moon.

The magnitude of the body which produced Mare Imbrium was such that it penetrated completely through the newly formed lunar crust and into the hot, liquid lava region below.

The crustal layer must have been broached as the lava was forced up by the pressure of the newly arrived mass until it filled Mare Imbrium, then burst through the gap between the Caucasus and Apennine mountain ranges into Mare Serenitatis where it covered the floor of this sea



Region of Mare Vaporum (upper center) showing splash craters radiating from Mare Imbrium (lower right). The mutilated wall (center) and pressure ridges in Mare Serenitatis are shown.

and then moved into Mare Tranquillitatis and beyond. In both of these latter seas the lava formed a crust before the flow stopped and, as a result, pressure ridges developed. In both of the maria the lava covered up any markings radial to Mare Imbrium, which might have been produced by the explosion.

In the other direction the lava destroyed the mountainous rim of Mare

Imbrium and then spread over the large area of the lunar surface now known as Oceanus Procellarum and Mare Nubium. Quite evidently these lava flows occurred after most of the craters had been formed as the partially drowned outlines of hundreds of craters are to be found near the edges of the sheets where the lava depth is least.

Hence Mare Imbrium and its associated lava outpourings came after the majority of the craters and because of the flows an essentially uniform scattering of craters was converted into an apparently uneven distribution.

The big meteorites fell, however, before the smaller crater-producing meteorites were all swept up. The last craters were formed after the lava flows had solidified and they are distributed essentially at random. These are the craters associated with ray systems.

Mare Serenitatis is believed to antedate Mare Imbrium as its walls have been extensively mutilated by the blast from the latter. Although Mare Serenitatis, Mare Crisium, and Sinus Iridum are probably crater seas smaller only than Mare Imbrium, no markings radial to any of them are found.

The splash craters themselves are on a lava flow, Mare Vaporum, but this sea does not have the same appearance as the other maria, and from its relationship to Mare Serenitatis, may well have been a lava discharge from the latter region, and thus be older than Mare Imbrium.

This, then, is a general picture of a logical succession of events and processes. In it is a satisfactory explanation of each of the major lunar structures and a time sequence for their formation which contains no contradictions or ambiguities. It remains only to subject each process to an analysis to establish whether or not it was capable of producing the observed result.

Size of the Meteorite Which Produced Mare Imbrium

Some thousands of years ago in Arizona a meteorite crashed to Earth, producing the largest known terrestrial meteor crater. While this crater is far tinier than the large ones found on the Moon, it nevertheless furnishes the only convenient subject for comparison. Examination has shown that very little of the explosive force was used in liquifying material. Most of it was spent in shattering and displacing the rocky layers of the ground and, presumably, the meteoritic mass.

When the large meteorite struck the Moon and created Mare Imbrium, great sheets of lava resulted. Hence it is inferred that the meteorite penetrated the recently formed crust into the still hot and liquid core. The mass of the lava displaced by the hydrostatic pressure of the new material was equal to the mass of the meteorite.

If an estimate of the mass of the lava sheets can be obtained an approximation to the size of the meteorite may be made.

Inspection shows that they cover a little more than one-third of the visible half of the Moon. Near the edges of the flows the walls of half

drowned craters project above the surface. Nearer to Mare Imbrium none are found. It is inferred that the lava depth is less than half a mile near the borders and considerably more than that in other sections. Let us assume an average thickness of one-half mile. We then have the equation:

$$\frac{1}{2} \times \frac{1}{3} \times \frac{1}{2} \times 4\pi r^2 = 4/3\,\pi R^3 \qquad (1)$$

where r = the radius of the Moon, 1081.5 miles, and R = the radius of the meteorite, whence

$$R = 66.4 \text{ miles.}$$

The above procedure implies equality of density of the lunar rocks and the meteorite. Actually, if the lunar lava is similar to the terrestrial forms, its density is about 2.8 while the general average for meteorites is about 3.4. This difference in density reduces the meteoritic radius so that

$$R = 62.3 \text{ miles.}$$

Let us assume that

$$R = 62.5 \text{ miles or } D = 125 \text{ miles.}*$$

Mass of the Meteorite

The density of the meteorite is assumed to be 3.4 and R = 62.5 miles. These lead to a mass of 1.4×10^{22} grams.

Depth to Which the Meteorite Penetrated

It is extremely difficult to make any concrete determination of this quantity, but it may be noted that Mare Imbrium varies between 750 and 650 miles in different diameters. The average diameter is 700 miles. An arc of this size is 56 miles above the corresponding chord at the midpoint. It seems probable that the meteorite penetrated at least this far below the surface.

Speed of the Meteorite at Impact

The velocity of a sound or shock wave in granite is 12,960 feet per second, or 2.45 miles per second. There is experimental evidence that the velocity decreases proportionally to the square root of the slope of the stress-strain relationship curve. Thus as long as the elastic limit of the material is not exceeded, the velocity of a shock wave decreases as the intensity of the shock increases.

In all probability, however, the collison was so violent that at no time was the impact an elastic one and therefore the velocity of propagation of the impulse is unknown. Let us assume that it was the same as the velocity of sound in granite, 2.45 miles per second. This speed is characteristic of many rocks. It would then take the shock wave 125/2.45 = 51 seconds to go completely through the projectile.

*Only one figure accuracy is claimed. However, 125 miles is the nearest whole number to the value derived, and has been retained for numerical convenience. If the mean lava depth were half as great as assumed the diameter would be 98 miles, and it would be 158 miles if the lava sheets were one mile thick.

Consequently the collision must have lasted at least 51 seconds because the rear of the projectile would not know that the front had struck the Moon for that length of time.

During these 51 seconds the front penetrated at least 56 miles below the surface. Therefore $56/51 = 1.1$ miles per second is an approximation to the minimum speed of penetration, but the latter averaged, probably, about one-half of the velocity at impact, which then becomes at least 2.2 miles per second.

It is possible that the shock wave would travel more rapidly than suggested, under conditions of the collison. This would act to increase the estimated velocity of impact.

It is realized, of course, that this is a very crude and rather dangerous way of determining the minimum velocity, but it gives a perfectly reasonable limit, as the velocity of escape of the Moon is 1.48 miles per second and the meteorite undoubtedly struck with a higher velocity than that.

It is important, however, for it points toward a low velocity of impact. If the meteorite were part of the material broken loose at the birth of the Moon, as suggested, it could hardly have had a high velocity relative to the Moon.

Nevertheless, due to the approximations made, it will be assumed that the meteorite was travelling about twice as fast as the above value, namely 4 miles per second. Even this value is near to the minimum possible.

The Kinetic Energy of the Meteorite

$$\text{Kinetic Energy} = \tfrac{1}{2}\, mv^2 \qquad (2)$$

With $v = 4.0$ miles per second the kinetic energy becomes 2.1×10^{11} ergs per gram, or 5,000 calories per gram. The total kinetic energy becomes 7.2×10^{25} calories.

Energy Necessary to Vaporize Rock

The specific heat of basalt, a typical igneous rock is 0.2 in the range of $0° - 100°$ C. For most materials the specific heat increases slowly with increasing temperature. Let us assume that the average specific heat is 0.25. The melting point of basalt is about 1200° C and the boiling point is probably about 4000° C. To raise the temperature of one gram of rock by 4000° requires something like 1000 calories. The heat of fusion may be estimated as not higher than 100 calories while about 400 calories may be needed to vaporize the stone. Hence roughly 1500 calories are necessary to vaporize one gram of basalt.

The above values are not known exactly, except for the specific heat of basalt in the low temperature range, but have been carefully estimated by comparison with known values for various solids. Even if the estimate were wrong by a factor of two there is still plenty of margin as 5000 calories per gram are available if the velocity of impact is only 4

miles per second.

By contrast, it requires only 1100 or 1200 calories per gram to vaporize iron from an original temperature of 0° C.

The Collision

While it is apparent from this calculation that the energy released at the collision was more than sufficient to vaporize the entire meteorite, probably only the surface layers of the meteorite and Moon in the contact region were turned into gas. The rest of the energy could not be so dissipated as the transfer of heat was too slow. It was utilized in shattering the meteorite and lunar rock layers and in displacing them.

Mare Imbrium is seven hundred miles in diameter. The mass of the spherical segment whose borders outline the great sea is only 2.6 times the mass of the meteorite if the density is 2.8 throughout the segment and hence ample energy was available to shift and distort this entire volume of rock.

As the meteorite struck, the resistance of the lunar material caused two things to happen. First, the surface layers vaporized, greatly increasing the already tremendous pressure. Second, the resultant force vectors were essentially at right angles to the meteorite's path as the vapors struggled to escape from the center of impact.

The back sections of the meteorite piled up against the frontal layers as the latter were slowed and, not being able to go forward freely, also spread out sidewise.

The net result was that the meteorite assumed a lens shape in which the whole mass moved downward, but the explosive action was mainly outward from the lens edge and thus roughly parallel to the lunar surface.

The released energy blew a gigantic hole into the Moon and sent a powerful shock wave through the ground layers along the chords of the segment. The mountain ranges bordering Mare Imbrium are regarded as being formed in part by this horizontal shock wave and in part by the material ejected from the explosion pit. The distorted meteorite is assumed to have buried itself in the new crater which probably was somewhat smaller than the present size of Mare Imbrium.

As a secondary effect, masses of rock were sent flying in all directions and with various velocities.

The Splash Craters

If the velocities of the ejected masses were greater than the velocity of escape, 1.48 miles per second, they would leave the Moon forever. If they were less than the circular velocity, 1.04 miles per second, they would plunge to the lunar surface at greater or lesser distances.

As shown previously many of the secondary masses did strike the surface and thus produced the splash craters, grooves, and ridges radial to Mare Imbrium.

The ridges are all very close to the border of the sea and, presumably, were formed from low velocity ejections; the elongated splash craters lie several hundred miles from the border while the grooves are still farther away.

If we select a typical splash crater we find it to be 40-60 miles long, 10 miles broad, and perhaps one-half mile deep. The equivalent volume of rock has thus been gouged out of the Moon by the projectile shot from the explosion area. This material was displaced on the averge by ten miles.

From these data we may compute how large a projectile was necessary to produce the observed crater.

The acceleration due to gravity at the Moon's surface is 5.4 feet per second per second. For short distances

$$R = v^2 \sin 2a/g \qquad (3)$$

where R is the range, v the velocity, a the angle of projection, and g is the gravitational acceleration.

Let $R = 10$ miles $= 52800$ feet, $a = 45°$, and $g = 5.4$ feet per second per second. Then $v = 530$ feet per second, or 0.1 miles per second.

This value may be considered as the average velocity at which the materials were gouged out of the splash craters.

From the dimensions of the average splash crater we may compute the displaced mass to be 2.3×10^{18} grams. Hence the energy needed to move this mass at this speed is 3.1×10^{26} ergs. The energy of the main explosion is 10^7 times greater.

In order to travel several hundred miles (300-800) the projectile must have been moving about one mile per second. We may equate the above energy to the kinetic energy of the projectile causing the splash crater and solve for its mass and then its diameter. The latter turns out to be 1.5 miles.

This process does not include the energies necessary to shatter the surface rocks and it also implies one hundred per cent efficiency. Probably a diameter of two miles would be a better value.

The Lava Flows

The last remaining step is to see if the lava sheets could remain liquid long enough to enable them to flow to their present dimensions.

On the airless Moon there are only two methods of heat loss, radiation to space and conduction to the ground.

Let us assume optimum conditions; the ground at 0° K and the lava at 3500° K, a difference of 3500° K. The heat conductivity of basalt, granite, and other igneous rocks is about 0.005 calories per second per square centimeter and so the heat loss by conductivity would be 17.5 calories per second per square centimeter. This value is a maximum for as the temperature gradient decreased the rate of heat loss would decrease.

The lava would quickly form either a cool layer on the top surface, or more probably, a still cooler crust. Let us assume the former and a temperature of 3000° K, maintained, for a time, by turbulence in the liquid.

According to the Stefan-Boltzmann law, $E = \sigma T^4$, a black body at 3000° K radiates 111 calories per second per square centimeter. This, too, is a maximum rate for as the energy is radiated the temperature drops and thus the rate of heat loss decreases.

We may neglect transfer of heat sidewise in as large lava sheets as these are. Therefore a maximum rate of heat loss is about 130 calories per second for each column of lava of one square centimeter cross section and one-half mile height. The latter value was estimated previously.

In order to cool one cubic centimeter of rock from 3500° K to 1200° K about 700 calories must be lost. In the above column there must be lost by the two methods at least 5×10^7 calories before solidification.

At the rate of 130 calories per second it would take over 4×10^5 seconds, or nearly one week. This is certainly a minimum estimate.

If the lava flowed for a distance of 1200 miles before it solidified it would have to travel at a maximum average rate of 11 miles per hour. This is an extreme value of the distance the lava covered and yet the velocity required is not excessive.

Summary

Previous theories of the origin of the lunar surface structures failed to find universal acceptance because of the simple fact that the markings used as illustrations probably could have been formed in several different ways. Since no conclusive observational test was made, conflicting theories have existed for some hundreds of years.

In this paper Mare Imbrium is identified as a gigantic crater. Its size precludes its being volcanic in origin, yet it must have been formed by a tremendous explosion. The only known source of sufficient energy is the collision of the Moon and a meteorite of the order of size of an asteroid. It was assumed that this actually happened and the process has been analyzed to see if it could produce the observed results.

It is concluded that this mechanism is entirely consistent with all observed conditions.

The impact caused the formation of the Alps, Caucasus, and Apennine mountain ranges which border Mare Imbrium and form its crater-like walls. In addition, numerous splash craters, grooves, and ridges radial to Mare Imbrium are found. They were caused by matter ejected from the explosion region.

The meteorite broke through the lunar crust and released tremendous amounts of very hot liquid lava from the Moon's interior. Since the lava was actually molten, it places the collision early in the Moon's his-

tory, soon after it divided from the Earth and before it could solidify completely.

Hydrostatic pressure from the newly arrived material forced the lava to the surface where it spread over large sections of the Moon. Many partially drowned craters still extend above the lava flow which thus came after most of the craters were formed. With any reasonable assumption as to the condition of the lava about a week would be needed to cool the liquid sheets to the solidification point and thus a speed of only eleven miles per hour would be necessary to allow the flow to spread to its greatest extent.

All features thus point to the identification of Mare Imbrium as the largest crater on the Moon. Similar to it in appearance are Mare Serenitatis, Mare Crisium, and Sinus Iridum. Probably they, too, are crater-seas.

Mare Serenitatis was formed prior to Mare Imbrium as its walls were deformed by the blast which produced the latter and its floor was covered by the lava outflow of its larger neighbor. Mare Crisium and Sinus Iridum cannot be so dated.

There is a smooth progression in diameters from Mare Crisium and Sinus Iridum to the largest of the usual craters, such as Clavius and Ptolemaeus. Because of the similarity in size and basic structure between the smallest of the meteoritic crater-seas and the largest of the normal craters, and because most of the craters must have been formed in the brief span between the birth of the Moon and the origin of Mare Imbrium, the craters, as a general thing, probably are also meteoritic in nature. If this view is correct, the crater forming material probably came from the fission region of the earth when the Moon was cast off.

Thus all the major lunar structures could have originated in a great series of meteoritic infalls. The successive operations outlined are all mutually consistent and capable of producing the observed results. As a corollary, vulcanism is merely a by-product of the main crater-forming processes.

It is believed that the preceding arguments establish the thesis that successive infalls of meteorites caused explosions from which the major lunar features originated.

REFERENCES

[1] *Pop. Astr.*, L, 365, 1942, Baldwin.

[2] *M.N.*, **91**, 169, 1930. Jeffreys suggests that frictional forces might not allow the Earth to break up thru tidal resonance. If this is true the Earth and Moon both probably were formed in the cataclysmic origin of the solar system. The actual mode of origin is not important to the main thesis of this paper.

[3] "The Earth," 1929.

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The Color Equation of a Visual Observer

By SERGEI GAPOSCHKIN

A variable star observer often has difficulty in harmonizing the published magnitudes of his comparison stars with the magnitudes as he sees them. In other words, the scale of published magnitudes does not coincide for some stars with that of the visual observer. This difference may or may not be real.

In the following note I have made a record of an attempt to determine the sensitivity of my eye when used in conjunction with a pair of binoculars in the observations of Nova Puppis 1942. In making estimates of brightness I have followed three rules: (1) The comparison stars used for an estimation were seen in the field of the binoculars at the same time as the nova. (2) The range of magnitudes within which one works with one instrument should not exceed 4. (3) During the estimates the exact magnitudes of the comparison stars were unknown to me.

The magnitudes of bright comparison stars for Nova Puppis were taken from Harvard Mimeogram, Series III, No. 1, 1938, and are on the Harvard photovisual system. These comparison stars supplied a good opportunity to determine the sensitivity of my eye (combined with the binoculars used). Eleven stars were selected (Table I) which cover a variety of spectra.

TABLE I

Star	Magnitude	Spectrum
ζ Pup	2.27	Od
α Pyx	3.68	B2
β Pyx	3.87	G5
q Pup	4.42	A5
r Pup	4.70	B3
HD 70002	5.44	K2
HD 69123	5.63	K0
HD 67977	6.06	G5
HD 68623	6.43	Mb
HD 69280	6.52	K2
HD 69066	6.78	K0

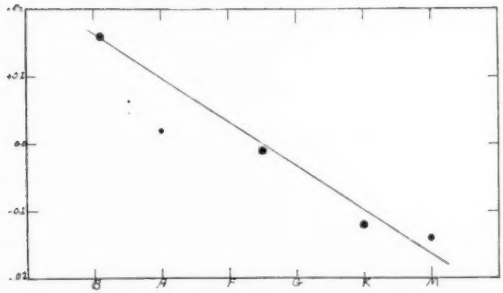


FIGURE 1

The Color Equation, Abscissae: Spectrum; Ordinates: Deviation.

In Table II I give my arbitrary scale, which expresses the relative differences of brightness of the comparison stars as I see them with the binoculars. These relative estimates were determined on ten nights, the best being December 7 and 8, 1942. Table II also contains my estimated magnitudes, obtained with the aid of the color equation of Table III and Figure 2.

TABLE II

MAGNITUDE AND SCALE ESTIMATES

Publ. Vis. Magnitude	Scale	Estimated Magnitude	Publ. Vis. Magnitude	Scale	Estimated Magnitude
2.27	62	2.09	5.63	11	5.73
3.68	40	3.52	6.06	6	6.12
3.87	35	3.93	6.43	2	6.60
4.42	29	4.36	6.52	1.5	6.64
4.70	25	4.55	6.78	0	6.88
5.44	14	5.56			

The mean value of the scale unit is determined to be $0^{M}.075$; and by comparing the resulting differences in magnitudes with the published differences in magnitudes we obtain the following table, which presents the color equation.

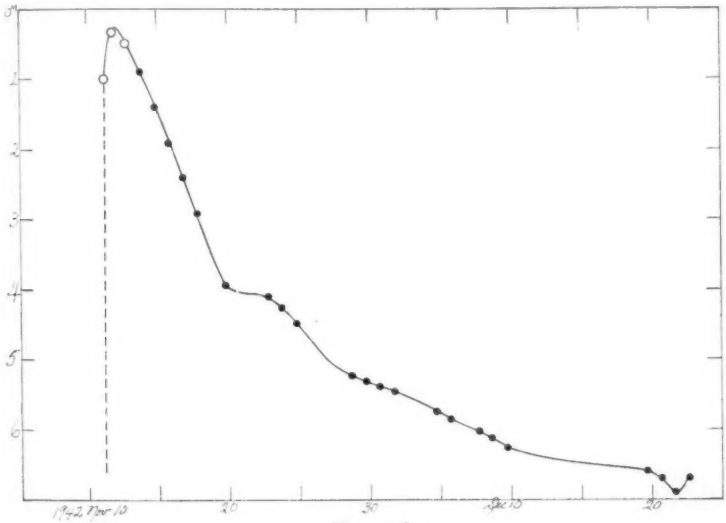


FIGURE 2

Light Curve of Nova Puppis 1942, Abscissae: Date; Ordinates: HP_V Magnitude. (Dots indicate observations by S. Gaposchkin, circles, observations taken from *Harvard Announcement Cards.*)

From Table III one derives the color equation as follows:

$$\Delta M = 0^{M}.20 - 0^{M}.0165 \times \text{Spectrum}$$

or using the color indices:

$$\Delta M = 0^M.05 - 0^M.13\, I_H,$$

where I_H is the color index on the system $(IP_g - HP_v)$. From these equations it appears that the sensitivity of my eye is slightly to the violet.

The observations may be summarized as follows: (1) My scale estimates are not linear functions of magnitude. (2) I see the blue stars relatively bright, the red stars relatively faint. Effect No. (1) will cause errors for extrapolated magnitudes, so that the nova's brightness may have been over-estimated at maximum. Effect No. (2) may have also

TABLE III

COLOR EQUATION AS FUNCTION OF SPECTRAL CLASS

Spectrum	Mean Deviation M	Col. Ind.* $I_{pg} - HP_v$
B1	+0.16	−0.22
A0	+0.02	0.00
F5	−0.01	+0.37
K0	−0.12	+1.20
M	−0.14	+1.66

*See C. Payne Gaposchkin (*H.A.*, **89**, 6, 1935).

caused the magnitude at maximum to be over estimated, since the Nova was then blue; but the bright comparison stars also were blue. Later, when the Nova became reddish, the reverse effect may have occurred. The total error over the whole range observed (4.5 magnitudes) cannot amount to more than $0^M.4$. In reality, when estimating within a small magnitude interval, the error due to color is much smaller, about one-tenth. In the interval A0 — G5 the color error is practically insignificant.

TABLE IV

MAGNITUDES OF NOVA PUPPIS 1942

Date 1942	(G.M.T.)	Magnitude	Date 1942	(G.M.T.)	Magnitude
November	13.85	0.9	December	1.78	5.45
	14.85	1.4		4.76	5.74
	15.85	1.9		5.75	5.85
	16.85	2.4		7.76	6.02
	17.85	2.92		8.65	6.12
	19.84	3.93		9.72	6.25
	22.84	4.10*		19.70	6.6‡
	23.84	4.25*		20.72	6.7‡
	24.84	4.48		21.70	6.9‡
	28.76	5.23		22.70	6.7‡
	29.77	5.31†			
	30.76	5.39			

*Nova is reddish-orange.
†Clouds.
‡Observations made with 4-inch comet seeker.

Differential extinction was serious only while the nova was brighter than magnitude 2.5. Two diagrams summarize the results given in the

present note. It may be mentioned that the low altitude of the nova made the observations difficult. In determining the color equation I made the simple assumption that the stars are all reddened to the same extent by differential extinction. If this assumption is unjustified, complications are introduced by the Purkinje effect and by differential extinction.

HARVARD COLLEGE OBSERVATORY.

A Simple Method of Determining the Date of the Equinox

By C. C. WYLIE

In an earlier paper,[1] it was pointed out that the diurnal path of a shadow on a level surface is a conic section, if one neglects curvature of the Earth, refraction, and the change in the declination of the Sun in a single day. If the Sun is below the horizon for part of the day, the path is a hyperbola. During our summer months the Sun is well to the north near rising and setting, and the hyperbolas formed by the shadow each day are concave to the south. During our winter months, when the Sun rises and sets to the south, the shadows are thrown to the north, and the hyperbolas formed by the paths of these shadows are concave to the north. At either equinox the Sun is in the plane of the equator, and the hyperbolas are changing from concave one way to concave the other. The diurnal path of a shadow, or of a spot of sunlight, is a straight line lying east and west at that time.

If the Sun just touches the horizon at midnight, the diurnal path is a parabola. If the Sun is above the horizon throughout the twenty-four hours, the diurnal path is an ellipse. At either pole, when the Sun is above the horizon, the diurnal path of the shadow is a circle.

The fact that, at either equinox, the Sun moves in the plane of the equator, means that the path of a shadow, or of a spot of sunlight made by light shining through a small hole, must move in the plane of the celestial equator that day. The intersection of that plane with another plane, either horizontal or vertical, is a straight line.

An interesting result is that the shadow of an east and west rail remains stationary throughout the day of the equinox. If a light snow occurs near March 21, that in the stationary shadow of the rail will melt more slowly than that in sunlight, and a conspicuous line of unmelted snow will remain for a time in the shadow. The illustration (Figure 1) shows this effect on an Iowa City street. If students are told about this, they will report many instances after a snowstorm near the spring equinox.

Early people fixed the date of the equinox from the rising due east

[1] "The Diurnal Path of a Shadow," POPULAR ASTRONOMY, Vol. 40, page 157; *Contributions of the University of Iowa Observatory*, Number 3, page 87.

and setting due west of the Sun. Temples were built to face the east, so that the priests, who regulated the calendar, could watch the east conveniently. By observing the path of a spot of sunlight, the date can be fixed quite easily. We have used a piece of rather heavy paper, pasted on a window at a height of about ten feet, and with a hole about half an inch in diameter, to make the spot of light. The following are some simple observations which students have found interesting.

1. Using an east or a west window, mark each day for some two hours the path of the spot of light on the floor. Note the day on which the path is most nearly an east and west line as indicated by the walls, or by grooves in the floor. This is a very simple observation, but if the building is not set with the points of the compass, the method will give an erroneous result.

2. Mark each day for some two hours the path of the spot of light on a blackboard on a wall running east and west, that is, a north wall in the Northern Hemisphere. Either an east or a west window can be used. Note the day on which the path is the most nearly horizontal. This is a simple method, but, if the blackboard is not set exactly east and west, some error will be introduced.

3. Mark each day, for some two hours in the forenoon, the path of a spot of light on the floor, using an east window. Then mark it for some two hours in the afternoon, using a west window in the same room or a nearby room in the same building. Measure carefully the direction, using the walls of the room or grooves in the floor. Note the date on which the direction in the afternoon is closest to the direction in the forenoon. That should be the date of the equinox. The accuracy of this method is not affected by the grooves or walls being out of an east and west line, since it fixes the date on which the path is a straight line.

4. Using a south window, mark the path of a spot of sunlight on the floor each day for some two hours, beginning about an hour before noon. Check the curvature of the paths with a yardstick or meter stick. The day on which the path is the closest to a straight line is the day of the equinox. This method is less accurate than Method 3, but it is the best for showing students that before the equinox the paths are hyperbolas concave one way, and after the equinox they are hyperbolas concave the other way.

5. Using an east window, mark the path of a spot of sunlight on a blackboard on a north wall for some two hours in the forenoon each day. Then using a west window, mark the path for some two hours in the afternoon. Measure the angle of rise or fall of the path. The day on which this angle is the same in the forenoon and afternoon is the day of the equinox. This fixes the date of the equinox, even if the blackboard is not due east and west, since it fixes the date on which the path is a straight line.

About the middle of March, 1940, pieces of heavy paper, about

10 x 12 inches and each with a hole about half an inch in diameter, were fastened to some windows of our office building about 10 feet above the floor level for a test of these methods of dating the equinox. Sunlight shining through the small hole made an elliptical spot of light on the floor of the room. In this building the floors are cement, and the center

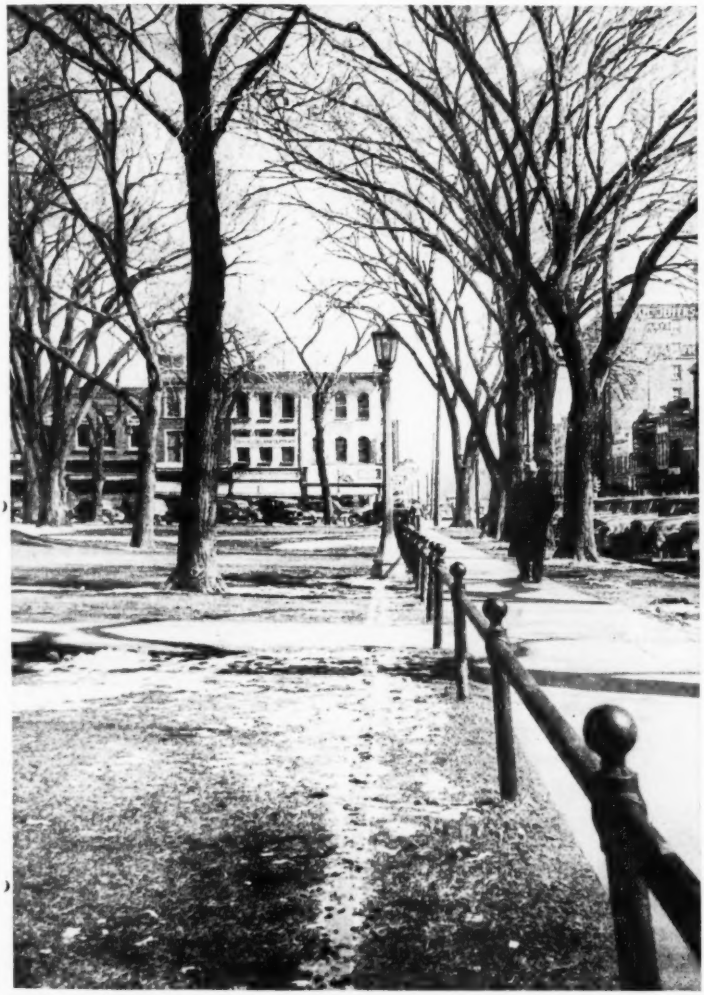


FIGURE 1

STATIONARY EAST AND WEST SHADOW ON DAY OF EQUINOX. NOTICE THE LINE OF UNMELTED SNOW.

of the elliptical spot could be marked closely with chalk by drawing approximately the major and minor axes of the ellipse and writing the hour and minute beside the mark. The grooves in the floor lie approximately in an east and west direction. An east window from which the spot of light fell on the floor was used, and also a west window from which the spot of light fell on the floor. With these, the date of the equinox was fixed by Method 1 and Method 3. A second west window was used from which the spot of light fell on a blackboard on a north wall. With this window, the date was fixed by Method 2. A smaller piece of paper was fixed to a south window from which the spot of light fell on the floor, but this was in another office, and as we did not want to bother the occupants of that office too much, no real measures were made. The path from this south window was marked on a few occasions, however. The use of the south window is Method 4. No east window from which the spot of light fell on a blackboard was available, so a test of Method 5 could not be made.

The path of the spot of light was marked on March 18, March 19, March 20, and March 21, although clouds interfered some on March 21. As the Sun moves across the sky from east to west, the spot of sunlight on the floor or on the blackboard moves eastward throughout the day. On the afternoon of March 18, the spot of sunlight on the blackboard rose about 4 inches between 2:00 P.M. and 4:00 P.M. On the forenoon of March 19, the spot of sunlight on the floor deviated to the south, as it moved to the east. On the afternoon of that day, the spot of light on the floor deviated to the north as it moved to the east. On the forenoon of March 20, the spot of light on the floor moved one inch to the north while moving 95 inches to the east. On the afternoon of that day, the spot of light on the floor moved one inch to the north while moving 85 inches to the east; the spot of light on the blackboard rose 11/16 inch in 142 inches of eastward motion. On the forenoon of March 21, clouds interfered, but the spot of light on the floor deviated to the north about ⅛ inch while moving to the east 25 inches. On the afternoon of that day, the spot of light on the floor moved practically parallel to the groove in the floor. On the same afternoon the spot of sunlight on the blackboard moved nearly horizontally, but dropped between ½ and ¾ of an inch in 14 feet of eastward motion.

Let us now fix the date of the equinox by Method 1, using the east window. On the forenoon of March 19, the spot of sunlight on the floor deviated to the south, and on the forenoon of March 20, it moved nearly parallel to the groove, but deviated a little to the north. This indicated that the equinox occurred between the forenoon of March 19 and the forenoon of March 20, but closer to the second date. Using the same method, and the afternoon observations, the spot of sunlight moved a little to the north on the afternoon of March 20 and practically parallel to the groove on the afternoon of March 21. This indicated that the

equinox occurred on March 21. The discrepancy between the forenoon and afternoon results indicates that the building is not set exactly with the points of the compass, but averaging these observations, one would assume that the Sun reached the equinox on March 20.

Let us now consider Method 2. The spot of sunlight falling on the blackboard from a west window rose rather rapidly on the afternoon of March 18, rose some on the afternoon of March 20, and dropped a little on the afternoon of March 21. This indicates that the Sun reached the equinox on March 21. This result is in agreement with the result from the spot of sunlight falling on the floor from a west window, and no doubt is slightly in error because the building is not set exactly with the points of the compass.

Let us now fix the date of the equinox by Method 3. On the forenoon of March 19, the spot of sunlight on the floor deviated to the south, and on the afternoon of the same day it deviated to the north. This indicated that the path was a hyperbola concave to the north, and that the Sun had not reached the equinox. On the forenoon of March 20, the spot of sunlight on the floor deviated about one inch to the north in 95 inches of eastward motion. On the afternoon of the same day it deviated one inch to the north in 85 inches of eastward motion. Since it deviated more rapidly in the afternoon than in the forenoon, the path was not exactly a straight line, but a hyperbola and still concave to the north. This indicated that it was still winter at Iowa City local noon. On March 21, in the forenoon the spot of light deviated to the north about $\frac{1}{8}$ inch in 25 inches of eastward motion, and in the afternoon it moved practically parallel to the groove in the floor. This indicated that the path was a hyperbola concave to the south and that at Iowa City local noon the Sun had passed the equinox. From the observations of March 20 and March 21, it appeared that the Sun reached the equinox between noon March 20 and noon March 21, Iowa City time, but closer to noon March 20. In reality, the Sun reached the equinox in 1940 at 12:24 P.M., Central Standard Time, March 20, so the result of Method 3 was essentially correct.

Teachers report considerable interest in Method 1 and Method 4 as home assignments, to be worked on the week-end nearest the equinox, weather permitting. Method 3, in general, has been used only where the teacher can supervise the observations, and see that the measurements are made with some care. Methods 2 and 5 require a blackboard, and so are worked usually at school. This year, the Sun reaches the equinox on Sunday, March 21, so if the weather is clear, interested students can verify for themselves that the path of a spot of light on the floor is a straight line lying in an east and west direction. Such students should be reminded that with War time, noon comes at about one o'clock, instead of at about twelve o'clock. Forenoon, noon, and afternoon observations should be planned accordingly.

UNIVERSITY OF IOWA, FEBRUARY 12, 1943.

Navigation with a Watch—I

By CHARLES H. SMILEY

With war being waged actively at sea by planes, surface vessels, and submarines, men occasionally find themselves on life-rafts or in life-boats far from friendly shores and with little or no equipment for navigation. It is the purpose of this article to show how one may find one's geographic position, both longitude and latitude, using only a watch and the tables given here. The tables with explanations may easily be printed on the two sides of a single water-proof sheet, 8 by 10 inches say, and attached with a small map of the oceans to the life-boats and life-rafts ahead of time.

The method presented here is in no sense a substitute for, nor an equivalent of any of the dozen or so excellent standard methods of celestial navigation. A watch was chosen as the single instrument to be used since modern water-proof wrist watches are widely owned and will probably share their owners' survival of any catastrophe. It is assumed that the person using the method understands simple interpolation.

Limitations

It seems wise to indicate the limitations of the method. The tables are for use only by a relatively motionless observer and they are useful only between 60° North and 60° South Latitude.

If the length of the day can be determined to within a minute, the latitude can be determined to within about 30 nautical miles (half a degree) except for about ten days before and ten days after the equinoxes, that is, approximately March 11 to 31 and September 13 to October 2. During these two intervals, the latitude is poorly determined by this device.

If the time of meridian passage of the Sun can be determined to within a minute, either by averaging the times of sunrise and sunset or by noting the time of shortest shadow of a vertical object on a horizontal plane, the longitude can be determined to within about 30 nautical miles.

Observations

For latitude, one finds the length of the day from the instant the top of the Sun first appears above the ocean horizon to the instant it disappears below the horizon. One should write down the times of sunrise and sunset and not count on remembering them. It may be noted that it is only the length of the day which counts in the determination of the latitude; the watch may have an unknown error and yet serve to determine the length of the day.

For longitude, the approximately correct time must be known. It is not to be expected that the watch will keep perfect time, but rather that the owner knows when it was last set and the approximate number of

minutes gained or lost in a week under normal circumstances. The owner must also know the number of hours to be added to or subtracted from the corrected watch time to get Greenwich Civil Time. For example, four hours are added to Eastern War Time, and seven hours to Pacific War Time to obtain Greenwich Civil Time.

The best way of determining the time of local noon, *i.e.*, meridian passage of the Sun, is to average the times of sunrise and sunset—to find the time midway between them. It will be wise to attempt to determine it independently as the time of shortest shadow of a vertical rod (a pencil or a stick) on a horizontal plane. Then if either the timing of sunrise or of sunset is missed, the length of the day can be calculated as double the interval from sunrise to noon, or double the interval from noon to sunset. It is suggested that one mark the end of the shadow of the vertical object frequently, noting the time of each mark. After the shadow has definitely begun to lengthen, one can look back and decide just when the shadow was shortest, perhaps interpolating between two times when the shadows were approximately equal.

Use of the Tables

Given the length of day for a known date, one wishes to find the latitude. From the table, the length of that day may be taken out for each of several latitudes which are considered reasonable. The observed length of day should lie between two of these, and one interpolates to find the latitude more precisely. An example is given below.

Hours and minutes are given in the table without a break; thus 922 means 9 hours and 22 minutes. In Leap Years, it is suggested that February 29 be counted as March 1, March 1 as March 2, etc., in entering the table.

Given the time of local noon, one seeks the longitude. Taking into account the time when the watch was last set, and how much it gains or loses per day, one subtracts or adds respectively the proper number of minutes to get the correct time. Then the appropriate number of whole hours is added or subtracted to obtain the Greenwich Civil Time on the 24-hour basis, the count beginning at Greenwich midnight. From the left-hand column of the tables, the *equation of time* in minutes of time is interpolated for the proper day and is then added, with sign as given, to the Greenwich Civil Time previously obtained. From this, twelve hours are subtracted if possible, otherwise twelve hours are added. The result is the longitude west of Greenwich in hours and minutes of time. This may be changed to degrees and minutes of arc by noting that one hour equals fifteen degrees; four minutes of time equal a degree; and one minute of time equals fifteen minutes of arc.

Example—May 5th, length of day 12:37, time of local noon, 10:54 A.M., Eastern War Time. Watch was set ten days earlier, loses five minutes a week. The observer is probably somewhere near the equator.

May 5th	0°	1207	1237	1255	6/24 of 10°	= 2.5°
	10° N	1231	1231	1231		
	20° N	1255	6	24	10° + 2.5° = *12.5° North Latitude*	

10:54 + 7 minutes + 4 hours + 3 minutes − 12 hours = 3:04 or
46° West of Greenwich.

It is hoped that persons using this method will remember its limitations and not expect too much of it. The following two problems and their answers are given for practice.

PROBLEM 1.—January 10, length of day 14 hours 16 minutes, observed time of local noon, 2:26 P.M., Pacific War Time. Watch set 30 days earlier, loses 5 seconds a day.

SOLUTION: 33°7 South Latitude, 140° 15′ West Longitude.

PROBLEM 2.—August 14, length of day 13 hours 56 minutes, observed time of local noon, 12:50 P.M. Eastern War Time. Watch gains 3 minutes a week, set two weeks earlier.

SOLUTION: 41°3 North Latitude, 69° 45′ West Longitude.

LENGTH OF DAY

		EqT	South Latitude 60°	50°	40°	30°	20°	10°	0°	North Latitude 10°	20°	30°	40°	50°	60°
Jan.	1	— 3	1843	1617	1459	1403	1319	1242	1208	1133	1057	1015	923	809	601
	11	— 8	1815	1602	1448	1356	1315	1240	1208	1135	1100	1021	932	824	626
	21	—11	1732	1538	1432	1346	1308	1236	1207	1138	1107	1031	947	846	704
	31	—13	1641	1508	1412	1332	1300	1232	1207	1141	1115	1044	1006	914	750
Feb.	10	—14	1550	1436	1351	1317	1251	1227	1207	1147	1124	1059	1029	946	840
	20	—14	1453	1358	1324	1300	1240	1222	1207	1151	1134	1116	1053	1021	934
Mar.	2	—12	1359	1322	1259	1242	1228	1217	1207	1156	1145	1133	1118	1058	1028
	12	—10	1305	1246	1233	1225	1217	1212	1206	1202	1156	1151	1144	1135	1123
	22	— 7	1211	1209	1208	1207	1206	1206	1206	1207	1208	1209	1211	1213	1218
Apr.	1	— 4	1112	1128	1139	1147	1154	1201	1207	1213	1219	1227	1237	1251	1312
	11	— 1	1023	1055	1116	1132	1144	1156	1207	1218	1231	1245	1303	1328	1407
	21	+ 1	929	1018	1050	1114	1133	1150	1207	1224	1242	1302	1328	1404	1501
May	1	+ 3	838	944	1027	1057	1123	1145	1207	1229	1251	1319	1351	1439	1554
	11	+ 4	747	912	1004	1043	1114	1141	1207	1233	1301	1333	1413	1510	1646
	21	+ 4	707	847	948	1032	1106	1138	1207	1237	1309	1345	1433	1538	1732
	31	+ 3	628	824	933	1022	1101	1135	1207	1239	1315	1355	1447	1601	1812
June	10	+ 1	604	811	924	1016	1058	1134	1208	1242	1318	1402	1457	1616	1839
	20	— 1	552	804	920	1013	1056	1132	1208	1242	1320	1405	1501	1622	1852
	30	— 3	557	807	921	1014	1056	1133	1207	1242	1319	1403	1459	1620	1846
July	10	— 5	617	818	929	1019	1059	1135	1208	1240	1316	1358	1452	1608	1825
	20	— 6	647	836	940	1027	1104	1136	1208	1238	1312	1350	1439	1548	1749
	30	— 6	731	902	958	1038	1111	1140	1207	1234	1304	1338	1422	1522	1705
Aug.	9	— 6	815	930	1017	1051	1119	1144	1207	1230	1255	1325	1401	1452	1616
	19	— 4	908	1004	1041	1107	1129	1148	1207	1225	1245	1309	1339	1419	1524
	29	— 1	956	1036	1103	1122	1139	1153	1206	1220	1235	1253	1314	1345	1431
Sept.	8	+ 2	1050	1113	1128	1140	1150	1159	1206	1215	1224	1235	1249	1307	1338
	18	+ 5	1145	1151	1155	1158	1201	1204	1207	1209	1213	1217	1223	1232	1243
	28	+ 9	1239	1229	1221	1216	1212	1210	1206	1204	1202	1159	1157	1153	1149
Oct.	8	+12	1328	1302	1245	1233	1223	1214	1206	1159	1151	1141	1131	1117	1056
	18	+15	1428	1342	1313	1252	1235	1220	1207	1153	1139	1124	1106	1040	1002
	28	+16	1522	1418	1337	1309	1246	1226	1206	1148	1129	1107	1041	1005	909
Nov.	7	+16	1615	1452	1400	1324	1256	1230	1207	1144	1119	1051	1017	931	817
	17	+15	1704	1522	1421	1339	1304	1235	1207	1140	1110	1038	957	901	728
	27	+13	1753	1550	1440	1351	1312	1238	1207	1137	1103	1026	940	835	646
Dec.	7	+ 9	1830	1611	1453	1400	1317	1241	1207	1134	1058	1018	928	816	613
	17	+ 4	1849	1621	1500	1404	1320	1243	1208	1132	1056	1013	920	806	555
	27	— 1	1850	1621	1501	1405	1321	1243	1207	1133	1056	1013	920	806	554
Jan.	6	— 5	1830	1611	1453	1359	1317	1241	1207	1134	1059	1017	927	815	612

The material in this article represents an expansion of a portion of each of two articles by the author, "Determining Latitude with Simple Instruments" and "Determining Longitude with Simple Instruments" which appeared in the *Providence Journal* on July 1 and August 1, 1941. One of the many books on navigation may present the method offered above but the author has not seen it in print. The lengths of days and the equation of time given were based on data in the *Nautical Almanac* for 1943. I wish to acknowledge the assistance of Miss Jean Roberts in the preparation of the tables.

LADD OBSERVATORY, PROVIDENCE, RHODE ISLAND, JANUARY 15, 1943.

Marvelous Voyages—VI

H. G. Wells' The First Men in the Moon-Part II

By LAURENCE J. LAFLEUR

We left Cavor and Bedford, it will be remembered, lost in the jungles of the Moon's vegetation. Their first evidence of animal life comes when they encounter huge "mooncalves," eighty feet in circumference and two hundred long, with an almost brainless head, fat-encumbered neck, slobbering omniverous mouth, little nostrils and tight shut eyes. These beasts are herded by selenites, comparatively small ant-like creatures five feet high and of generally human proportions: two legs, two arms, torso, neck and head, but the head having two eyes set at the side. Their bodies are encased in leather clothing and their heads in a large spiked helmet used for prodding refractory mooncalves. It is not long before information is forthcoming as to how mooncalves and selenites pass the long lunar night: Cavor and Bedford come upon a circular open space some two hundred yards in diameter, which is the metal cover of a pit. It opens, almost hurling Bedford into the abyss, and revealing more selenites in the illumination below.

Being thirsty and hungry they succumb to the temptation to eat lunar vegetation. "The stuff was not unlike a terrestrial mushroom, only it was much laxer in texture, and as one swallowed it, it warmed the throat." It also intoxicated the two men, and during their relatively helpless condition they were taken prisoners by the selenites.

The selenites have bulging eyes at the side, no nose, a downwardly curved mouth like a human mouth in a face that stares ferociously. The neck is jointed in three places, and at the end of their arms is a sort of flap and thumb like the end of an elephant's trunk.

Cavor concludes that they are a couple of thousand feet inside the surface, possible even a mile, because it is cooler, because their voices are no longer faded as they were on the surface, and because the curious feeling in the ears and throat has disappeared. "The moon must be enormously cavernous with an atmosphere within, and at the center of

its caverns a sea. One knew that the Moon had a lower specific gravity than the earth; one knew that it had little air or water outside; one knew, too, that it was sister planet to the earth and that it was unaccountable that it should be different in composition. The inference that it was hollowed out was as clear as day. Kepler, with his 'subvolvani,' was right after all." He supposes that "On any planet where there is an intelligent animal, it will carry its brain case upward, and have hands and walk erect"; and he is optimistic about establishing communication, possibly on Galton's plan of demonstrating geometrical propositions. Communication is in fact established, but on much more elemental lines than these, for the selenites, after feeding them on damp, meringue-like mooncalf, indicate by signs that Bedford and Cavor are to follow them.

On their way to lower levels they pass huge machinery which produces an incandescent fluid which illuminates the underworld with a cold blue light. They come to a plank over an abyss, across which the selenites walk unconcernedly, but which is impassable to an untrained man, particularly with his hands tied. In the resulting impasse, Bedford, who has managed to free his hands, is pricked with a goad and punches his tormentor. "There came another of those beastly surprises of which the Moon world is full. My mailed hand seemed to go clean through him. He smashed like some softish sort of sweet with liquid in it. He broke right in. He squelched and splashed. It was like hitting a damp toadstool. The flimsy body went spinning a dozen yards and fell with a flabby impact. I was astonished. I was incredulous that any living thing could be so flimsy." Bedford then releases Cavor as well as himself, and the two make a running fight for the Moon's surface. On the way up they pass a lunar slaughter-house where mooncalf meat is being prepared, and Bedford remarks: "I do not remember seeing any wooden things on the Moon; doors, tables, everything corresponding to our terrestrial joinery was made of metal, and I believe for the most part of gold, which as a metal would, of course, naturally recommend itself—other things being equal—on account of the ease in working it and its toughness and durability."

Finally they achieve the outer air, which was intensely hot and caused the men great physical discomfort. They have about four terrestrial days of sunlight to find the sphere, and separate for the search. Bedford finds it, but in returning for Cavor discovers that the latter has been wounded and captured by the selenites. Bedford almost overstays the lunar day, and has to make a race for the sphere against the cold of lunar night. "Before me the pale serpent-girdled sector of the Sun sank and sank and the advancing shadow swept to seize the sphere before I could reach it. I was two miles away—a hundred leaps or more—and the air about me was thinning out as it thins under an air pump, and the cold was gripping at my joints. . . The nearer I struggled, the more impossibly remote it seemed. I was numb, I stumbled, bruised and cut my-

self and did not bleed. . . I crawled. The frost gathered on my lips, icicles hung from my mustache, I was white with the freezing atmosphere. . . I pulled myself in. There lurked within a little warmer air. The snowflakes, the airflakes, danced in about me, as I tried with chilling hands to thrust the valve in and spin it tight and hard."

So Bedford escapes from the Moon, but he must still manage to return to the Earth. He experiments with the blinds. The first one he opens shows him the Sun. "After thinking a little I started upon the windows at right angles to this one, and got the huge crescent Moon and the little crescent Earth behind it." He figured his best chance was to "drop back towards the Moon as near as I dared in order to gather velocity, then to shut my windows and fly behind it, and when I was past to open my earthward windows and so get off at a good pace homeward." So by great good luck he reaches the Earth safely, his fall being into the sea near England. By an unfortunate accident the sphere is lost, and with it the secret of Cavorite.

But the story is not quite ended. Some time afterwards, radio messages come from the Moon, and though they are fragmentary, they continue the story of Cavor, who, captured by the selenites, was able to report many circumstances of the Moon and its inhabitants.

First of all, the Moon, to a depth of a hundred miles, is quite spongy naturally; but in addition has been extensively excavated by the selenites. The excavated material, piled around the shafts, constitutes what we have mistakenly called craters. A hundred miles down is a sea, moved by solar tides, and like all water on the Moon, luminous with a cold blue light. In the recesses of the caverns near the sea there are some wild and dangerous monsters that have never been exterminated, such as the "Rapha, an inextricable mass of clutching tentacles that one hacks to pieces only to multiply; and the Tzee, a darting creature that is never seen, so subtly and suddenly does it slay." The caverns of the Moon, on the whole, are very windy places. As the sunlight comes round the Moon, the air in the outer galleries on that side is heated, some flows out on the exterior and mingles with the evaporating air of the craters, where the plants remove its carbonic acid; while the greater portion flows round through the galleries to replace the shrinking air of the cooling side that the sunlight has left. There is, therefore, a constant eastward breeze in the air of the outer galleries, and an up-flow during the lunar day up the shafts."

The selenites are built on the arthropod principle, although they have four limbs like man. They exaggerate the caste principle found in ants, and are built in such a way as to fit their occupations. They differ in size, hue, and shape. For example, Cavor met some who "bulged and overhung, some ran about among the feet of their fellows, some twined and interlaced like snakes. . . One had a vast right forelimb, an enormous antennal arm, as it were; one seemed all leg, poised as it were on stilts;

another protruded an enormous nose-like organ beside a sharply speculative eye that made him startlingly human until one saw his expressionless mouth . . . The strange head of the mooncalf-minders underwent astounding transformations; here it was broad and low, here high and narrow, here its vacuous brow was drawn out into horns and strange features, here it was whiskered and divided, and there with a grotesquely human profile. . . There were amazing forms with heads reduced to microscopic proportions and blobby bodies; and fantastic flimsy things that existed it would seem only as a basis for vast, white-rimmed, glaring eyes. . . Some have single or paired bunches of three or five or seven digits for clawing, lifting, guiding. Some have enormous rabbit-like ears just behind the eyes; some whose work lies in delicate chemical operations project a vast olfactory organ; . . . and others, who I have been told are glass-blowers, seem mere lung-bellows. . . Fine work is done by fined-down workers amazingly dwarfed and neat." Incidentally, the lunar eyes are said to see heat as well as light, so that any difference in temperature renders an object visible. Among the female selenites some are specialized as mothers, just as in the social insects.

The mental capacities of the selenites vary as do their physical properties. Three selenites were appointed to study Cavor, all having enormous brains, but developed in different regions. One was a general intelligence, one a master of intricate analogy, and one a phenomenal memory. This last, is one of a class that replaces libraries and all other written records on the Moon. Lunar libraries are congresses of living brains.

Political organization in the Moon is a complete monarchy, under the Grand Lunar, a being practically all brain. Here we find the apotheosis of a planned economy: individuals manufactured to fit precisely into the places where they are needed. And when there is a temporary excess of any kind, the individuals are put into an artificial coma and preserved until they are again wanted.

The selenites are aware of the theoretical possibility of Cavorite, but are unable to make it because helium is completely lacking in the Moon. Cavor, who has rashly informed the Grand Lunar of the bellicose nature of mankind, is interrupted in his last message in an attempt to transmit directions for making Cavorite, and the inhabitants of the Moon successfully preserve, for this generation at least, their splendid isolation.

The Determination of the Course at Any Point on a Great-Circle Voyage

By FREDERICK C. LEONARD

The problem, for which a solution is proposed in the following paragraphs, is discussed in various places in the literature on navigation. Because of the interest recently aroused in the study of navigation and because of its importance in present-day activities, it may be not amiss to give this detail of a very extensive subject an independent setting.

One of the fundamental problems that arises in connection with great-circle sailing between 2 points on the surface of the Earth—whether by sea or by air—is the problem of determining the course at *any* point on the voyage. A simple analytic solution of this problem, the practical application of which entails the use of only logarithmic trigonometric tables, is herewith presented.

In the spherical triangle ABD (see the accompanying figure), A is the initial point (or point of departure) of the voyage, B the final point (or destination), and D the geographic pole, while a, b, and d are the sides respectively opposite the angles at A, B, and D. d is evidently the great-circle distance between the points A and B. If λ_1 and L_1 are the longitude and the latitude of A, and λ_2 and L_2 the corresponding coordinates of B, then $a = 90° - L_2$, $b = 90° - L_1$, and $D = \lambda_2 - \lambda_1$.

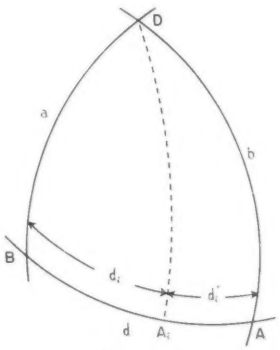


FIGURE 1

The formulae for the solution of the distance d between the points A and B are, then, as follows:[1]

[1] See, *e.g.*, W. W. Campbell's "Elements of Practical Astronomy," 2nd ed., Macmillan, § 10, p. 14, where the analogous astronomical problem, "Given the right ascensions and declinations of 2 stars, required the distance between them," is worked out.

$$g \sin G = \cos L_1 \cos (\lambda_2 - \lambda_1) \quad (1)$$
$$g \cos G = \sin L_1 \quad (2)$$
$$\tan G = \operatorname{ctn} L_1 \cos (\lambda_2 - \lambda_1) \quad (3)$$
$$\tan B = \tan (\lambda_2 - \lambda_1) \sin G / \cos (L_2 + G) = \tan (\lambda_2 - \lambda_1) \sin G \sec (L_2 + G) \quad (4)$$
$$\tan d = \operatorname{ctn} (L_2 + G) / \cos B = \operatorname{ctn} (L_2 + G) \sec B \quad (5)$$

In the foregoing formulae, g is an abstract positive quantity and G an auxiliary angle, introduced to render the final equations of a form suitable for logarithmic computation. The quadrant of G—since g is positive—is fixed by the signs of the right-hand members of eq. (1) and (2), while the quadrant of B, which, in the nature of the case, cannot exceed 180°[2], is either the first or the second, according as tan B (in eq. (4)) is positive or negative. Eq. (5) gives the *angular* distance between the points A and B and also the *linear* distance between them, in *nautical miles,* if d is expressed in *minutes of arc.*

To find now the course—*i.e.,* the angle at A_i in the spherical triangle A_iBD—at *any* point A_i on the run, the following formulae may be employed:[3]

$$f \sin F = \cos L_2 \cos B \quad (6)$$
$$f \cos F = \sin L_2 \quad (7)$$
$$\tan F = \operatorname{ctn} L_2 \cos B \quad (8)$$
$$\tan A_i = \tan B \sin F / \sin (d_i - F) = \tan B \sin F \csc (d_i - F) \quad (9)$$

In the preceding formulae, f is a positive number and F an auxiliary angle, the quadrant of which is uniquely determined by the signs of the right-hand members of eq. (6) and (7), angle B is defined by eq. (4), and d_i is the distance between the point A_i and the destination B. If the distance traveled (in nautical miles or minutes of arc) from the starting point A to *any* point A_i on the route is represented by d_i', then

$$d_i = d - d_i' \quad (10)$$

The value of d is calculated from eq. (5), while that of d_i' is known from the log (or the dead-reckoning position) of the ship or airplane.

The *initial course* is evidently the course that applies when the point A_i coincides with A (the point of departure), $d_i' = 0$, and $d_i = d$, while the *final course—i.e.,* the course that obtains on arrival at B (the destination)—is equal obviously to the *supplement* of the angle B in the original triangle ABD.

If, on the other hand, the longitude λ_i and the latitude L_i of the point A_i are known, the following equations, formed by analogy with (1)-(5), will serve to evaluate the course at A_i and the distance d_i from A_i to B:

$$h \sin H = \cos L_2 \cos (\lambda_i - \lambda_2) \quad (11)$$
$$h \cos H = \sin L_2 \quad (12)$$
$$\tan H = \operatorname{ctn} L_2 \cos (\lambda_i - \lambda_2) \quad (13)$$
$$\tan A_i = \tan (\lambda_i - \lambda_2) \sin H \sec (L_i + H) \quad (14)$$
$$\tan d_i = \operatorname{ctn} (L_i + H) \sec A_i \quad (15)$$

Department of Astronomy, University of California, Los Angeles,
1942 December 23.

[2] It is assumed that the terrestrial triangle ABD has been so chosen that no side or angle of it shall exceed 180°.

[3] See, *e.g.,* W. Chauvenet's "Plane and Spherical Trigonometry," 11th ed., Lippincott, § 70, pp. 179-81.

Marvelous Voyages—VI

ERRORS IN WELLS' THE FIRST MEN IN THE MOON—PART II

By LAURENCE J. LAFLEUR

1. For an animal built on a plan comparable to that found on earth the difficulty of large size is only in part eliminated by lesser gravitation. On the Moon, the mooncalves' bulk would not be too great for their muscles. But there would be the problem of getting oxygen to the cells of the body, a problem which becomes more difficult with increasing size and which would be aggravated by the tenuous atmosphere of the Moon. Consequently an animal of the given size would not be possible without an improved form of breathing apparatus. But the mooncalves had "little nostrils."

2. The "curious feeling in the ears and throat" is evidently due to low atmospheric pressure. But if so it would disappear gradually instead of remaining until the men go underground.

3. The different densities of Moon and Earth are readily accounted for by the difference in compression in the two bodies. Also, if the Moon was torn from the earth, it would have a greater proportion of the lighter surface materials.

4. There is no good general reason why the brain-case should be upward, or why an intelligent being should walk erect, and many cases where that would not occur can be thought of. If eyes are on stalks, for example, and if tentacles are present in addition to four or more legs, there would be no reason for a changed method of locomotion.

5. They would have hands, or reasonable substitute therefor.

6. Gold is not a suitable metal for most uses. It is hard, indeed, to think of any which is intrinsically less useful. That it has been used by primitive mankind is to be explained in terms of its availability, not utility.

7. Gold is not a common metal on earth. There is no reason to suppose that it would be much more common on the Moon. Of course, with deep caverns available, the heavy elements might be relatively more common, but this factor should not make very much difference.

8. If two miles is not much more than 100 leaps, a leap is about 100 feet. This is too much. Suppose an ordinary man raises his center of gravity a foot and a half in leaping on earth, and has a forward velocity

sufficient to carry him four feet forward at the top of his leap. If he lifts his feet a foot and a half, he will carry forward a little farther than double the distance, and make his total leap 9.656 feet. If such a man leaps with the same velocities on the Moon, he will reach a height of 9 feet, carry 48 feet forward without the extra distance gained by lifting his feet, and, with the extra distance, 49.924. If we assume that he jumps with the same force on the moon, thus giving maximum instead of minimum distances, he leaps 64.992 feet without and 66.432 with the extra distance. And all this is figuring on a single leap: a man cannot keep it up for a hundred leaps or more at any such rate. Wells has therefore at least doubled, and probably much more than doubled, the length of a leap.

9. The Moon would not cool so rapidly, even without an atmosphere.

10. There would be a strong eastward wind under the conditions Wells pictured, a wind of more than hurricane force, produced by the pressure of hot air to the east. For a short time there would be a cold breeze in the reverse direction in the lower levels. These currents would make the cooling process even longer than it would be otherwise.

11. Air would liquefy at low temperatures, not sublimate and crystallize into airflakes.

12. If air cooled to such a point, Bedford would be dead in less than a minute.

13. Even at much higher temperatures than those required to solidify air, a single lungful would freeze the lungs and kill.

14. The sphere landed in the dawn when the Moon was at its aphelion. Hence it was on the forward meridian of the Moon. It left half a month later, at perihelion, hence at right angles to a line from Sun to Earth while the Moon is between them. The Moon would thus appear to Bedford as a half-moon, not crescent.

15. The earth would be full, not crescent.

16. The Earth and Moon would be 90 degrees apart, not in line with one another.

17. The sphere could not pass the Moon as stated. It left the Moon in a straight line; if it returned by lunar gravitation it would hit the Moon squarely. Given sufficient time for the Moon to swing around the Earth in its orbit, or allowing the Sun's influence to be felt for some time, it would be possible to pass the Moon, but not in the way described by Wells.

18. The Moon can't be spongy to a depth of a hundred miles. For reasons, see the discussion of Jules Verne's "Journey to the Center of the Earth."

19. Crater walls are not excavated material. They do not have that appearance, there would be no reason to discard material in such a form, and this would not account for the great differences in size in craters,

particularly for craters a hundred miles in diameter.

20. A race more civilized than man, and very much better organized, would have no trouble exterminating monsters.

21. The breeze would be westward in the morning, eastward in the evening.

22. The breeze would be downward during the day.

23. Living brains would not be a good substitute for libraries. They are too perishable.

24. If helium were lacking in the Moon, it could be manufactured more easily than any other element.

The Planets in April, 1943

By ALICE H. FARNSWORTH

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours, etc. War Time in each zone is one hour later than standard. Phenomena are described as seen from latitude 45° N. *The American Ephemeris and Nautical Almanac* is the source of the data.

Sun. The Sun moves from a position in the constellation Pisces ($\alpha\ 0^h\ 38^m.2$, $\delta + 4°\ 6'.9$ on April 1) into Aries ($\alpha\ 2^h\ 29^m.4$, $\delta + 14°\ 44'.3$ on May 1).

Moon. Times of phenomena in April:

		h	m
New Moon	April 4	21	53
First Quarter	12	15	04
Full Moon	20	11	11
Last Quarter	27	7	51
Runs high	April 11	12	
In Apogee	12	22	
Runs low	25	9	
In Perigee	25	16	

This month provides a favorable opportunity for photographers to demonstrate the eccentricity of the Moon's orbit from the varying apparent diameter of the Moon. Photographs of the Moon made for example with a telescope about ten feet long on the dates of apogee and perigee show images that differ in diameter by as much as an eighth of an inch. In April and May the relation of dates of apogee and perigee to phase is such that both photographs can be obtained at convenient hours, weather permitting.

The occultation of Aldebaran by the Moon on April 9 (see Occultation Predictions, page 152) may be regarded as a call to service for any who are interested in starting a program of useful observing. Aldebaran is so bright that it makes a good object to begin on. Suppose we discuss briefly the *why, when,* and *how* of observing occultations.

Why observe occultations? The Moon is the slipperiest customer in the sky as far as keeping accurate track of its path is concerned. The theory of its motion, to begin with, is incredibly difficult and complicated. Even when the experts in lunar mechanics have completed their work and given us tables which indicate

exactly how the Moon may be expected to move, it is so big and bright an object that recording precisely where it really is at a given moment becomes a difficult matter in itself.

The case for stars is quite different. Their point-like aspect, lent by great distance, makes them capable of being accurately located with relative ease, either by photographic or visual means. So they come to our assistance in locating the Moon. At the precise moment when a star is in the act of disappearing behind the limb of the Moon, the star and a certain point on the Moon's limb coincide for that instant. Obviously the precisely-known position of the star furnishes an instantaneous position of a point on the Moon's limb, useful information provided we record accurately the instant when the two coincide.

When are these helpful stars to be found disappearing behind the Moon? Each month (*cf.* page 152) POPULAR ASTRONOMY, as one of its regular services, records for three stations in the United States the stars of sixth magnitude and brighter which lie in the path of the Moon. With the G.C.T. of each immersion (and emersion as well) are given quantities *a* and *b* which combine with the difference between the observer's position and the standard station to provide corrections to the predicted G.C.T. This corrected value may then be converted to war time in his own district. An example is given below.

Because the Moon's motion is eastward among the stars and the east limb is defective (unilluminated) before Full Moon, it is obvious that immersions occurring between the dates of New and Full Moon occur at the dark limb. When the limb is faintly lit by earthshine, the observer is relieved of the strain of wondering where the limb is, and conditions may be said to be ideal. Immersions at the dark limb are most easily observed, are therefore made with the least percentage of error, and are the most desired by those checking the Moon's motion. Emersions and waning-Moon immersions are good practice, however.

How is the observation made? Well before the predicted time of the phenomenon, the observer points the telescope at the Moon and locates the star in question, guided by the quantity "Angle East from North point" of the Moon's disk, indicated in the tabular data. It is well to remember that a slight change of focus may mean the difference between finding and not finding a faint star in moonlight. The focus on the lunar features is in general not the best for the star. If the star can still be seen clearly defined when at some distance from the center of the field, it is a good idea to reduce glare by leaving the bright lunar disk mainly outside the field of view during the tense moments before the disappearance occurs. If you do not have a driving-clock, you will find it convenient to place the star at the edge of the field at such an interval before the expected time of the occultation that it will have drifted approximately to the center by the time it disappears.

The observation is in a sense twofold: the eye notes the star's disappearance (this is instantaneous), and the observer at this exact instant takes some action which assures accurate timing of the phenomenon. This timing is the crux of the whole matter, but should not form an insuperable obstacle in these days of radio time-signals.

If you are blessed with an assistant whose eye is upon the seconds-hand of a reliable time-piece, your sharply-spoken signal "Go" or "Time" will enable him to record probably to a fraction of a second the reading of the time-piece. Many observers, operating alone, punch a stop-watch at the crucial instant. It is per-

haps a better plan to *start* the watch (rather than stop it) at the telescope, since in case of an erroneous impression (*i.e.*, if a passing cloud briefly obscured the star which shines serenely forth a little later) the watch can be hastily re-punched twice over and so be ready for a fresh start. Best of all as a signalling device at the telescope is a (carefully tested) chronograph key which writes a signal among uniformly recurring signals from a reliable clock, solar or sidereal.

Having captured the occultation in terms of the reading of the watch, one must somehow use its reading to furnish the correct time of the observation. Go immediately to a reliably running standard clock and stop the watch when the clock reads an even minute. (If additional check is desired, simultaneous readings of the running watch and the standard clock can be secured before the watch is stopped.) Subtract the watch-reading from the coincident clock-reading, to give the clock-time of the observation; then apply the known error of the clock to give correct standard time of the occultation.

The error of the clock may be determined by frequent comparisons with time signals received from the United States Naval Observatory. The Naval Observatory broadcasts time signals from Arlington four times a day, during the five minutes just preceding 0^h, 6^h, 12^h, and 18^h Eastern War Time, on frequencies 113, 4390, 9425, and 12630 KC. The United States Bureau of Standards in Washington broadcasts a musical note 24 hours a day over WWV on 5000 KC. This note has superposed upon it a second-beat and in addition the note is stopped at 0, 5, 10, 15 . . . 55 minutes after the hour and started again at 1, 6, 11, 16 . . . 56 minutes after the hour. This signal is based on a master-clock corrected after comparison with the Arlington time-signals. Frequently continuous time signals on the American system, with a new cycle of signals every five minutes are heard at about 3400 or 6800 KC. These seem to be accurate enough for occultation timing. It is believed that they come from a Canadian station.*

It will be evident that in order to report the time of the occultation correct to within a second or less (the accuracy desired by the computers) the greatest care must be taken with each of the various steps that lie between the event and the report.

In order to be useful the observation must be made from a known position on the Earth, *i.e.*, latitude, longitude, and elevation. If you have no other means of determining it, find yourself on a U.S. Coast and Geodetic Survey map of the region and interpolate with all possible care between the meridians of longitude and the latitude circles there given.

Here are a few warnings (for the serious observer).

Don't neglect any observation on a clear night. You will probably miss two-thirds of the stars on your list anyhow because of bad weather.

Don't be discouraged by broken clouds. Sometimes the star is in the one hole.

Don't place too great faith in the accuracy of your prediction. Be ready *at least* a minute ahead, then keep your attention as well as your eye on the star.

Don't on the other hand fatigue the eye by watching steadily for several minutes before the event can possibly take place.

Don't assume the rate of your time-piece to be negligible unless you have tested it carefully and repeatedly. Make the necessary comparisons as promptly as possible.

*The writer is indebted to Dr. C. H. Smiley of Ladd Observatory for details regarding time signals.

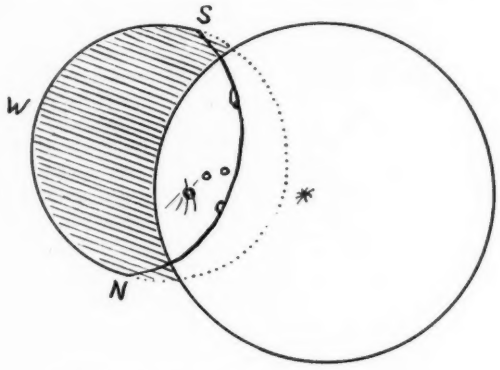
Don't depend on your memory for any watch-comparisons. Write everything down at once, then check and re-check your arithmetic.

Don't attempt to correct your result for reaction time or other suspected delay. In suspicious cases, report pertinent details.

Don't fail to report your observations, with your position, preferably at the end of each quarter year, either to Dr. Dirk Brouwer, Yale University Observatory, New Haven, Connecticut, or to the writer (at Brigham Hall, South Hadley, Massachusetts).

Don't be surprised if you find the pursuit of occultations wholly fascinating.

The story of how the time of an occultation observed and reported by you is eventually made to test how accurately the Moon is following the path laid down for it in existing tables is reserved for a later time. The following account of an actual observation will illustrate several of the points mentioned above.



Aldebaran and the Moon before the occultation of January 16, 1943, as seen in a 4-inch telescope. The (dotted) limb was invisible, the shaded portion outside the field.

The occultation of Aldebaran on January 16-17, 1943, was to be observed at Ladd Observatory, Providence, Rhode Island (λ 71° 24′ W, ϕ 41° 50.3 N). The prediction formula is:

$$\text{G.C.T. at place} = \text{G.C.T. at standard station} + a\,(\lambda - \lambda_0) + b\,(\phi - \phi_0).$$

The nearest standard station is the eastern one (λ_0 72° 30′ W, ϕ_0 42° 30′ N) given first in POPULAR ASTRONOMY for December, page 554. Therefore $\lambda - \lambda_0 = -1^{\circ}.1$ and $\phi - \phi_0 = -0^{\circ}.7$.

For the immersion of α Tauri, we find

G.C.T. Jan. 17 $2^h\,28^m.4$ $a = -2^m.1$ $b = -0^m.4$ whence
$a\,(\lambda - \lambda_0) = +2.3$ $b\,(\phi - \phi_0) = +0.3$
Sum Jan. 17 $2^h\,31^m.0$ G.C.T. whence
Jan. 16 22 31.0 E.W.T., prediction for Providence.
Angle East from North 89°

The Moon was nearly twelve days old. Copernicus was conspicuous, with Reinhold and Landsberg above. Gassendi and Kepler were on the terminator.

Aldebaran appeared about on a line drawn through Lansberg perpendicular to the visible terminator, in accordance with the predictions that it would disappear at a point 89° E of N on the Moon's limb. The limb (dotted in figure) was completely invisible. Most of the bright area of the Moon (shaded in the drawing) was placed deliberately outside the field of the 4-inch telescope, used with a magnifying power of 60. The figure shows the position of the star a few minutes before the Moon moving towards the right in the inverted field blotted it from view.

At the moment of disappearance a stop-watch was started (reading: $0^m\,0^s$). As soon as conveniently possible, a known tick from a Molyneux clock reading eastern standard time was compared with the coincident reading of the stop-watch, then checked again 25° later, as follows:

Clock time	$21^h\,33^m\,30^s.0$	$55^s.0$	
Reading of stop-watch	2 24.8	49.8	
Clock time of occ.	21 31 5.2		
Error of clock	0 0		whence
E.S.T. of occ.	21 31 5.2		

Thus the immersion occurred only a tenth of a minute after the predicted time. The procedure employed in the comparison of time-pieces differs slightly from that described earlier.

Mercury, at superior conjunction on April 4, passes rapidly through perihelion on April 15 and out to its greatest elongation east of the Sun on April 30. A spring elongation such as this one always provides the most favorable chance to see Mercury at a considerable altitude in the western sky after sunset. Night after night for more than a week it can be seen in the fading sunset glow, higher up each night until the 30th when it will occupy a position very close to the Pleiades. After that date it swings back again into the Sun's rays.

Venus, moving out rapidly eastward from the Sun, is conspicuous in the west after sunset. It moves from the constellation Aries into Taurus, passing Uranus on April 18, and 3° north of Saturn on April 25. The fact that it comes to perihelion on April 26 has only a slight effect on the apparent motion of this planet whose orbit is so nearly circular that its least distance from the Sun differs by less than 1½ per cent from its greatest distance.

Mars remains an inconspicuous morning object low in the southeast before sunrise. The waning crescent Moon comes into conjunction with it on April 29, occulting it as seen from low latitudes.

Jupiter, at eastern quadrature on April 6, is moving slowly eastward in Gemini, just north of δ. It forms a prominent triangle with Castor and Pollux. The First Quarter Moon (then in apogee) passes south of it on April 12.

Saturn remains near ϵ Tauri in the Hyades, where it has hovered for months. For the next six months, however, it will be moving eastward. It is still well placed for telescopic study in the early evening. Venus passes 3° north of it on April 24-25.

Uranus, bright enough to follow with an opera-glass, crosses a line joining 32 and 43 Tauri about the middle of April, and is midway between 43 and the brighter 37 Tauri during the last few days of the month. (See chart in the January issue of POPULAR ASTRONOMY, page 35.) On the evening of April 17-18 Venus,

moving about 25 times as fast on the celestial sphere as Uranus, passes by 1½° to the north, overtaking Saturn a week later.

Neptune continues its retrograde motion in Virgo. (See chart in the January issue, page 35.)

Occultation Predictions for April, 1943

(Taken from the *American Ephemeris*)

Date 1943	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION *a*	IMMERSION *b*	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION *a*	EMERSION *b*	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′										
Apr. 1	μ Cap	5.2	9 9.7	..	..	6	9 27.8	..	..	332
8	75 Tau	5.3	22 52.9	—1.4	—1.0	88	0 8.2	—1.0	—0.9	256
9	264 B.Tau	4.8	0 32.6	..	..	161	0 48.2	..	..	187
9	275 B.Tau	6.5	1 53.7	+0.2	—2.6	131	2 35.0	—0.3	+0.3	220
9	α Tau	1.1	2 50.0	+0.2	—1.2	93	.. ..	..	..	...
10	115 Tau	5.3	3 9.5	+0.9	—4.0	155	3 34.3	—0.7	+1.4	206
11	71 Ori	5.2	1 3.6	—1.5	0.0	60	2 3.9	—0.3	—2.8	309
16	45 Leo	5.9	4 39.9	..	..	180	5 10.3	..	..	229
16	ρ Leo	3.8	7 25.9	+0.2	—2.4	153	8 7.4	0.0	—0.8	246
22	γ Lib	4.0	5 6.9	—1.9	+0.7	87	6 18.4	—1.4	—1.1	316
22	η Lib	5.6	10 28.0	—1.0	—2.3	141	11 16.8	—0.3	—0.6	240
27	υ Cap	5.3	8 18.5	—1.1	—0.1	133	9 4.4	—1.6	+2.4	210
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′										
Apr. 9	α Tau	1.1	2 55.9	0.0	—2.0	116	3 47.8	—0.2	—0.3	236
11	71 Ori	5.2	0 30.2	—2.0	—0.3	81	1 54.5	—1.4	—1.8	284
16	ρ Leo	3.8	7 39.8	..	..	184	8 0.2	..	..	221
22	γ Lib	4.0	4 39.2	—1.0	+0.3	117	5 51.8	—1.5	+0.2	289
22	η Lib	5.6	10 10.2	—1.4	—2.2	144	11 5.7	—1.2	—0.5	243
26	*f* Sgr	5.1	11 4.5	—2.1	—0.1	104	12 19.9	—1.7	+0.4	239
28	44 Cap	6.0	11 4.1	..	..	12	11 41.5	..	..	316
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′										
Apr. 10	119 Tau	4.7	5 27.2	—0.8	+0.3	49	6 13.3	+0.4	—2.6	314
10	120 Tau	5.5	6 2.4	—0.4	—0.3	62	6 53.3	+0.5	—1.9	301
14	o^2 Cnc	5.6	7 42.7	—0.6	—1.4	102	8 47.9	—0.1	—1.8	296
14	o^1 Cnc	5.2	8 8.8	..	..	184	8 25.2	..	..	213
17	σ Leo	4.1	6 12.6	—2.2	—0.8	102	7 34.5	—1.3	—2.3	316
18	10 Vir	6.1	5 56.2	—2.4	0.0	95	7 14.4	—1.4	—2.3	326
22	γ Lib	4.0	4 35.1	+0.6	—2.5	171	5 5.0	—1.4	+3.4	230
22	190 B.Lib	6.4	8 43.5	..	..	40	9 10.4	..	..	3
25	29 Sgr	5.4	12 40.0	—2.1	+0.7	64	13 57.3	—2.2	—1.1	290
26	*f* Sgr	5.1	10 17.1	—1.0	+0.1	122	11 19.3	—1.9	+1.7	235
28	44 Cap	6.0	10 16.8	—0.8	+2.6	37	11 3.8	—0.6	+0.2	303
28	45 Cap	5.9	10 37.7	—0.3	0.0	128	11 20.6	—1.2	+2.8	210

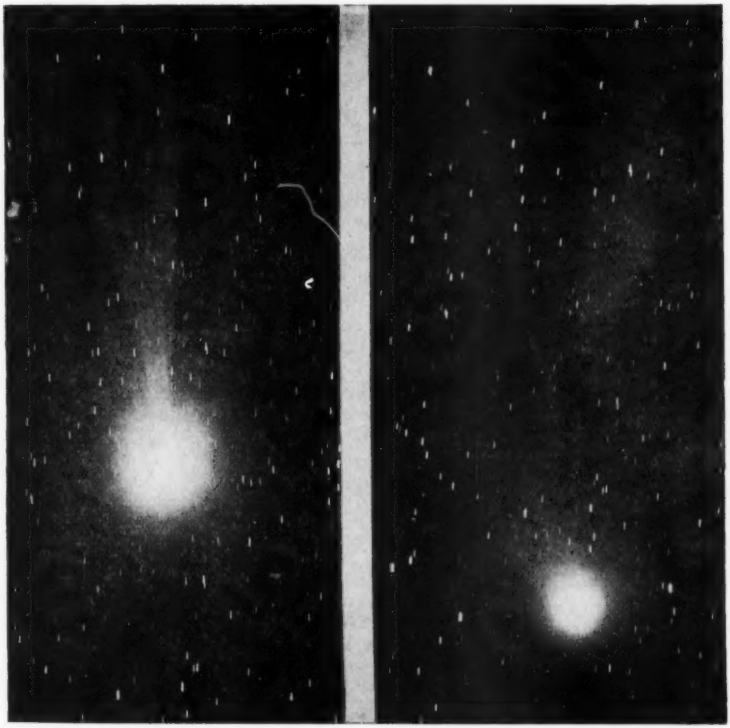
The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to

the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Comet Notes

By G. VAN BIESBROECK

COMET 1942*f* (WHIPPLE). This bright comet has followed well the course predicted by the preliminary parabolic orbit computed by the discoverer (see p. 102 of the February issue). Observers have been surprised to find this object much brighter than was predicted. It became quite conspicuous to the naked eye, the more so since the Ursa Major region crossed by the comet is poor in stars. My naked-eye estimates of total brightness indicate a maximum of magnitude 3.9 on January 26-27 but in February the decrease set in and by February 8 the brightness had dropped to 4.8.



COMET 1942*f* (WHIPPLE)

Two half-hour exposures with the 24-inch reflector of the Yerkes Observatory on January 27 (left) and January 28 (right), 1943.

On clear nights the large hazy coma and a faint tail could be recognized with the naked eye. In the telescope it offered an interesting subject of study: the two aspects (January 27 and 28) reproduced herewith side by side illustrate the rapid changes that occurred in the tail. They are from 30 minute exposures with the 24-inch reflector of the Yerkes Observatory, the plate being guided on the comet so that the stars appear as trails. The comet's motion across the sky was rather slow: the stars near the lower edge of the picture on January 27 will easily be recognized above the coma on January 28. On the first date a well-defined conical beam seems to emanate from the large head, in the center of which there was a small sharp nucleus of magnitude 7 which in the picture is lost in the glare of the head. On January 28 the ejection of tail material appears much less active but at a distance of about one degree from the head the bright material of the previous night is still conspicuous, drifting away from the coma. Diffuse streamers emitted by the head also have changed considerably in the interval. The rapid change indicated by these plates induced the writer to take a series of exposures on February 3 and this brought out clearly how the tail material was thrown out in space with a velocity of 30 to 40 kilometers per second away from the head. These plates suggest also that only the brighter part of the tail is recorded in the field of some two degrees angular extent. Exposures made here with a fast small camera have indicated a length of tail of at least six degrees on February 2.

The object is and will remain very well located for further observation. The ephemeris given on page 103 of the preceding issue requires only a small correction; it shows that the comet will stay in the Big Dipper until the middle of March and that during the last week of February it will be inside the bowl near the star γ Ursae Majoris. Naked-eye visibility is to be expected until the end of February.

Comet 1942 *c* (Oterma) is now losing in brightness. It is moving slowly across the constellation of Auriga, a very favorable location, but it will require large telescopes to be picked up in the coming month. The following ephemeris computed by P. Herget from Bobone's orbit (p. 53 of the January issue) indicates its course during the next dark of the Moon:

Ephemeris of Comet 1942 *c* (Oterma)

1943	α h m	δ ° ′	M
Feb. 21	5 26.6	+39 52	11.9
Mar. 1	5 46.1	40 31	12.2
9	6 6.2	40 50	12.5
17	6 26.6	+40 50	12.8

When last recorded here (February 7) the magnitude was estimated as 11.5; the comet showed a well-condensed though not stellar nucleus and a faint fan-shaped tail on the following side.

Comets Oterma and Whipple are the only two comets now known to be observable. The search for the two expected periodic comets Reinmuth and Neujmin (*2*) has not yet led to their recovery. Both must be fainter than magnitude 16 since they could not be located on plates exposed by the writer at the end of January showing stars as faint as magnitude 17.

Williams Bay, Wisconsin, February 10, 1943.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Recently I decided to undertake the determination of radiants from some of the observations sent in during previous years and those of 1939 were first chosen. Many hours of work have been spent on them by me and these Notes will contain only a partial report as more 1939 maps are still to be studied. In the following list I have endeavored to include only those whose existence seemed pretty well proved. When any with less than 4 meteors are included it is for some unusual reason. In general the A.M.S. rules, long since published, have been followed. But a word should be said about the serial numbers. Some time ago the system was changed from a series without gaps to one in which, at first, the year after 1900 was made the *first two* of a number with 4 digits. This soon left such enormous gaps that it was discarded, and I am now trying to fill up some of these unused gaps. As the exact date is always given, the A.M.S. radiants could be, if desired, catalogued eventually by dates, but, if so, the serial numbers would have to vary greatly. This word of warning is given so that no reader will think that the serial numbers have anything to do with the dates on which the radiants were observed, or even, necessarily, with the years.

As usual, I had to decide what work was good enough to use and what not for this purpose. Fortunately, in many cases there is an easy test. If an observer sends in maps with meteors plotted on or about the Perseid, Orionid, Leonid, or Geminid maximum, and the plotting is so bad that no reasonably decent radiant can be derived for the stream in great activity for the date in question, it is to me positive proof that the observer plots so poorly that any other apparent radiant on his maps may be considered fortuitous, and I lay aside his maps so far as radiants are concerned until he shows definite improvement. Those observers who will not take the trouble to learn the constellations well are doomed never to become even fair meteor plotters. Also those who observe very seldom cannot be in good practice. Further, it seems that some few persons do not have the necessary eyesight or quickness of judgment, because accurate meteor plotting needs both to a large degree. Therefore the number of maps with plotted meteors, useless for radiants, is large indeed! On the contrary, a few from the very first seem to do good work, and many by the second year send in excellent reports. It must not be inferred that the maps, discarded as to radiant determination, are useless, for this is far from being the case. They are valuable for many statistical studies and are therefore carefully preserved. Also their accompanying record sheets can be used with them in a large number of problems, so no observer need feel that his work was useless or will be neglected. However, each should strive to improve his plotting, no matter how good it may be or he thinks it is, and this improvement comes only from actual practice and not just theorizing about how to do it. One of our rules or requests is that members send in their original maps and, if they desire, make and keep copies for themselves. Many do the opposite, perhaps rather ashamed of the untidy appearance of the maps used outdoors, often in dew, and smudged by pencil or soiled hands. However, we do not mind the untidy appearance of the originals and these are what we want!

For each time a copy is made errors probably creep in. Also I can more easily decide about doubtful points when the original can be studied. This rule should be called to the strict attention of our members. In the following list an asterisk after the observer's name indicates that the maps submitted to me were copies, not the originals.

A.M.S. No.	Observer and Station	1939 Date	Radiant α	Radiant δ	No. →	Acc.	Notes
1709	Parker, P. O., Ooltewah, Tenn.	8 10.77	45.5	+56.5	11	VG	Perseids
1710	Stone, W. R., Santa Barbara, Cal.	4 20.84	276	+37.5	4	G	Lyrids
1711	" "	11 14.88	68	+12	6	G	
1712	" "	11 15.92	144	+21	3	P	Leonids
1713	" "	11 16.94	148	+25	11+	G	Leonids
1714	" "	12 13.9	110	+30	17±	F	Geminids
1715	Pirsig, G., Blue Earth, Minn.	5 16.±	209	+19	5	G	
1716	" "	8 9.74	40	+56	4	F	Perseids
1717	Green, G., *Pittsfield, Mass.	8 10.75	44	+40	4	G	Perseids
1718	" "	8 10.75	42	+54	9+	G	Perseids
1719	" "	10 20.76	96	+16	5	VG	Orionids
1720	Wetherill, G., Upper Darby, Pa.	10 21.95	91	+11.5	16+	F	Orionids
1721	Corbett, M., New Haven, Conn.	10 19.76	91	+14	5-7	FG	Orionids
1732	" "	11 14.8	106	+59	7	F	
1723	Neale, J. J., New Haven, Conn.	4 20.78	269	+39	8	F	Lyrids
1724	" "	4 22.71	277	+36	7—	F	Lyrids
1725	" "	8 10.81	46	+53	9—	FG	Perseids
1726	Avery, V., Banks, N. D.	10 9.+	257	+56	2	?	Giacobinids?
1727	" "	10 8.+	335	+42.5	6	F	
1728	Halbach, E. A., Beaver Dam, Wis.	8 12.76	44	.55	3	G	Perseids
1729	Armfield, L., M.A.S. Obs., Wis.	8 12.79	46	+54	10+	F	Perseids
1730	Klaas, P. N., Dubuque, Iowa	9 14.65	322	+37	5-6	F	
1731	" "	9 16.62	285	+66	7+	F	
1732	" "	10 2.58	25	−15	3	G	
1733	" "	10 10.72	149	+30	6	G	
1734	Johnson, H. M., Des Moines	8 12.80	50	+53	23+	F	Perseids
1735	Komaki, K., *Kanaya, Japan	10 20.32	91.4	+13.5	4	G	Orionids
1736	" "	10 21.32	93.0	+15.0	13	VG	Orionids
1737	" "	10 22.32	96.0	+15.7	7	G	Orionids
1738	" "	12 12.07	111	+33	6	G	Geminids
1739	" "	12 13.04	111.3	+33.2	16+	VG	Geminids
1740	" "	12 14.33	112.3	+32.5	14±	VG	Geminids
1741	" "	12 14.33	140	+12.5	6	FG	
1742	" "	12 15.02	90	+11	3	G	
1743	" "	12 20.32	179	+41	5-6	F	
1744	" "	12 20.32	188	+27	4	F	
1745	" "	12 21.30	228	+75	7	VG	
1746	Heaton, G., Tuscaloosa, Ala.	6 21.84	296	+38	5	G	
1747	" "	8 9.80	45	+56	8+	P	Perseids
1748	" "	8 9.80	330	−13	6—	F	
1749	" "	12 13.76	0	−35	3	?	
1750	" "	12 14.74	112.0	+30.5	10	VG	Geminids
1751	Faulkner, D., †Stetson Univ., Fla.	4 20.72	283	+36	4+	F	Lyrids
1752	" "	10 20.78	92	+12.5	14+	FG	Orionids
1753	" "	11 15.80	150	+23	8+	G	Leonids
1754	" "	12 12.83	115	+30	18+	G	Geminids
1755	" "	12 12.83	155	+19	6±	F	

†Leader of a large group of student observers.

Several very brilliant fireballs have been reported in recent months by only one person, though usually seen over very populous areas. These reports have reached me too late, in general, to ask the help of the press in locating other

observers. With all the airplane spotters now on the lookout, it seems that reports should grow not decrease in number. I do not believe it could possibly interfere with the duties of spotters if they made mental notes on a fireball seen during their watch and put these on paper as soon as relieved. I heartily commend such a procedure to their attention, further asking that such notes be sent to A.M.S. headquarters here. With so many of our best active members in military or naval service and others very busy in civilian defense, we need all the outside help we can secure to keep our Society from reaching a low level of activity.

FIREBALL OF 1936 MAY 17

On this date at about 7:45 P.M., E.S.T., a bright fireball passed over Ohio from S.W. to N.E. For the stations of most of the observers this was only a few minutes after sunset, hence the sky furnished no stars as reference points. Observations were therefore mere estimates or, at best, referred to some landmark. Early in June, I received from Dr. J. J. Nassau, director of Warner and Swasey Observatory, Cleveland, Ohio, a number of reports that had come to him and which he thought might be used. Almost simultaneously I received from Mr. J. L. Black of Cleveland, long an active member of the A.M.S., a carefully condensed series of reports he had gathered and, in practically every case, he had personally interviewed the observer, measuring the altitude and azimuth of the points where they said the fireball had first and last been seen. As Black used our standard questionnaire, all possible information was extracted from the people interviewed. Thirteen reports from Nassau and 15 from Black gave me a rather large number to work with, though unfortunately about one-half came from or very near Cleveland. On plotting the azimuths upon a specially prepared map, as is routine practice, I ran into several contradictions. Fortunately, however, the average of the values of the better observers at Cleveland, S14, seemed fairly certain, and also the average values of the three observers at New Philadelphia, S26. All of both groups had been interviewed by Black. Also we had the definite statement that it passed west of the zenith at Oberlin, S2, at $h = 70°$. This helped place the projected path as west of that place. After some trials, I finally hit upon a projected path which, when the observed altitudes were brought in, gave satisfactorily the beginning height, the height of a point near the end, and the height of the end point itself. All these points indeed lie almost exactly on a straight line. Observations from 6 stations were used to determine the first of these heights, from 3 to determine the second, and from 2 to determine the actual end. The average deviations from the adopted means for these points were, respectively, ± 18, ± 4, and ± 0 km. If the weights of the observations were allowed for, the ± 18 km would drop to ± 5 km for observations of unit weight. These small deviations indicate that the adopted path is more nearly correct than the ones generally derived from reports of miscellaneous observers where not a single one was trained in astronomy and where stars could not be used as reference points.

The fireball was yellow-blue or yellow-white in color, reported like the planet Venus, and doubtless much brighter, as Venus would hardly be noted by most people just after sunset. The fireball was definitely called "brilliant," despite the strong sky illumination. Indeed from S2, where it passed very near the zenith, it was said to be: "Not quite the size of the full Moon." Near the two-thirds point of its path it divided into two parts, which were about 30′ apart and which continued their flight one a little ahead of the other. There was no "explosion"

seen, only a division. No long-enduring train was left. Meteorites could hardly be expected from so great an end height. The flight took 4.1 seconds—mean of 11 uninterviewed persons; but only 2.2 seconds mean of 10 interviewed! It seems almost certain that even the larger figure is a considerable *underestimate* as the path was about 248 km long and so nearly horizontal. I am under great obligations to Dr. Nassau and to Mr. Black, particularly to the latter who spent so much time and trouble in personal interviews. The derived data on the path follow:

Date	1936 May 17/18; 7:45 P.M., E.S.T.
Sidereal time at end point	166°—
Began over	$\lambda = 83° 09'$ W : $\phi = 40° 29'$ N ; at 90 km
Ended over	$\lambda = 81° 12'$ W : $\phi = 42° 12'$ N ; at 52 km
Length of path	248 km
Projected length of path	247 km
Velocity	??
Radiant (uncorrected)	$a = 40°$, $h = 9°$
Zenith correction	—10°.6
Radiant (corrected)	$a = 40°$, $h = -1°.6$; $\alpha = 116°$, $\delta = -35°$

Many of our members have sent in their 1943 dues of $1 without forcing the sending of bills. This is a great help to me as, for the moment, no staff assistance is available due to war emergencies and absences. Will those who have not yet paid please follow the excellent example of their fellows?

Flower Observatory, Upper Darby, Pennsylvania, 1943 February 16.

Second Note on the Probable Mass of the Object which formed Meteor Crater

By C. C. WYLIE

In the discussion which followed the presentation of the paper, "Calculations on the Probable Mass of the Object Which Formed Meteor Crater," to the members of the American Astronomical Society, three points were raised which may be of general interest to readers. These were: (1) Because of the great size of Meteor Crater, rock thrown out of the crater would be thrown a greater distance than would be necessary in oil company craters. (2) How can meteorites the size of the Grootfontein and the Cape York remain intact when striking, if an object the size of that computed for Meteor Crater would explode as calculated? (3) The assumption of a spherical shape tends to give a smaller mass than is probable. The three points had been considered, and let us take them up in order.

The Nitroglycerin Equivalent for Meteor Crater

The Stanolind Oil and Gas Company reported by letter that an efficiently placed charge of 1000 pounds of explosive would produce a crater about 200 feet in diameter and 20 to 25 feet deep, with the rock fractured some distance below the bottom of the crater. Meteor Crater is about 4000 feet in diameter and 600 feet deep. Comparing the heat of combustion of the explosive with that of nitroglycerin, and comparing the volume of the explosion crater with that of Meteor Crater, one can calculate that 2200 tons of nitroglycerin would be necessary to produce Meteor Crater. However, to avoid, or minimize, any error due to the extra force required to throw material out of a hole the size of Meteor Crater,

we included for Meteor Crater, but not for the explosion craters, the volume of the material shattered, but not thrown from the crater. One should keep in mind that most of the material shattered remained in Meteor Crater. Next, to avoid overestimating the efficiency of the Meteor Crater explosion, a figure approximating the most inefficient, rather than the mean, of the several explosion craters considered was adopted. In this way the figure previously given was raised by a factor of more than fifty, to the equivalent of 125,000 tons of nitroglycerin for Meteor Crater. This is about as high a figure as the present data will permit.

The Grootfontein Meteorite

Let us now consider the Grootfontein (sometimes called the Hoba West) meteorite. According to L. J. Spencer,[1] the present dimensions of the relatively flat top of the meteorite are about 10 feet by 9 feet, and the present weight, estimated from the specific gravity and the volume, is about 60 metric tons. From the thickness of the surrounding iron shale, presumably the result of oxidation of the meteorite, the original dimensions of the top were about 12 feet by 11 feet, and the original weight was about 88 metric tons. The metal is "comparatively soft and quite malleable," and "there are no indications of Widmanstätten figures or Neumann lines." The meteorite is embedded in a soft limestone, from the description a variety intermediate between ordinary limestone and chalk.

Fisher calculated[2] that the Grootfontein meteorite would drive 827 centimeters (about 27 feet) into clay soil, or 80 centimeters into limestone. His formula, however, did not include cosmic velocity, and presumably his calculations were for ordinary limestone, rather than the soft variety in which the Grootfontein meteorite is imbedded. We are of the opinion that there may have been an appreciable residual of cosmic velocity, an almost horizontal component, and that the meteorite encountered first a soil lighter than ordinary clay.

Since this meteorite is the record in size, it seems reasonable to assume that it entered the atmosphere at a very low angle with a velocity near the minimum possible, and that it struck the Earth's surface at a relatively high velocity for a meteorite, but in relatively light soil, which reduced its velocity so that it did not shatter when striking the soft limestone in which it is embedded. From the fact that it is quite malleable, the meteorite may have been flattened some without shattering at the time of striking.

The thickness of the surrounding iron shale indicates that the meteorite is quite old, even geologically speaking, so there may well have been plenty of soil over the limestone in which it is now embedded. It has even been suggested that the meteorite might have fallen when that area was under ocean water, but the compression of the limestone implies that the meteorite struck after the area was elevated from the sea.

The formula for striking velocity of a meteor has been previously given as $V = V_o/(1 + A)$, where V_o is the velocity with which the meteor enters the atmosphere, and V is the striking velocity. For known meteorites, the following expression for A is more convenient than the one used in the previous article.

$$A = c\,\sigma\,G \csc \alpha / mb$$

where c is the cross section of the meteorite in square centimeters, m is the mass in grams, σ is the surface density of the atmosphere, b is the coefficient of varia-

[1] *Mineralogical Magazine*, Vol. 23, pp. 6-8, 1932.

[2] *Proceedings National Academy Sciences*, Vol. 19, p. 288, 1933.

tion of density of the atmosphere with height, α is the angle of fall, and G is 2, an empirical constant. Applying these formulas to the Grootfontein meteor, and assuming $V_o = 8$ miles per second, we find that for a striking velocity of ½ mile per second, $\alpha = 10°8$. For a striking velocity of ¼ mile per second, $\alpha = 5°2$. These figures for striking velocity are on the order of the velocities of projectiles used in modern warfare, and appear possible. Angles of fall of 5° to 10° are not unduly low.

Hence, by the formula for resistance of the air used in the calculations on Meteor Crater we find that, under the proper conditions, a meteorite the size of the Grootfontein (practically 100 American tons originally) can strike and remain unshattered; but these largest meteorites known must have struck under most favorable conditions to remain unshattered.

Effect of Non-spherical Shape on the Meteor Crater Object

Let us now consider the third point, that the meteorite may not have been spherical. At the velocities with which meteors move, the retarding effect of the air depends primarily on the mass and on the area of the cross section presented to the air. The Grootfontein meteorite, for example, was a rather flat piece of nickel-iron of density 7.96, originally of mass 88 metric tons, or 97 American tons, and with an effective cross section of about 132 square feet. The retarding effect of the atmosphere on this meteorite was approximately what it would have been on a stone meteorite of weight 97 American tons, of radius 6½ feet, with a cross section of area of 132 square feet, and of density 2.86.

It was thought that the average reader would prefer to have the results for nearly spherical objects, but to allow for some irregular deviations which would increase the area of the effective cross section, a density of 7.0 was used in the calculations of the earlier paper. This density is below that of nickel-iron, and so allows for a certain amount of irregularity.

To illustrate the fall of a rather flat object, it was assumed that the meteor which produced the crater was flattened enough to be equivalent to a sphere of density 2.86. For an entrance velocity of 15 miles per second, it was found that the striking velocity was 8.3 miles per second, and the mass 11,000 tons. A block of nickel-iron 58 x 52 x 15 feet would have the right mass, and, falling broad side, would present the right cross section to the air. For an entrance velocity of 10 miles per second a mass of 21,000 tons was found. The figures given in the earlier paper for a sphere of density 7.0 were 8,000 tons and 16,000 tons, respectively. Hence, the assumption of this considerable amount of flattening increases the mass required by not quite 50 per cent.

Summary

In estimating the nitroglycerin equivalent of the energy required to produce Meteor Crater, the volume of the shattered material was added to that of the hole proper for Meteor Crater, but not for the craters produced by explosives. The adopted figure, instead of being the mean, is near the maximum of the results obtained by comparison of Meteor Crater with the explosives craters.

The formula for resistance of the air used in calculating the mass of the object which produced Meteor Crater permits the Grootfontein meteorite, practically 100 tons originally, to remain unshattered after striking, but conditions must have been favorable.

Some non-sphericity was allowed for in the calculations by using for the

density a figure a little below the density of nickel-iron. The assumption that the object producing Meteor Crater had a thickness about one-fourth the average of the other dimensions increases the masses given in the earlier paper by less than 50 per cent.

In the earlier paper it was stated that the diameter of the object probably was between 35 and 50 feet, and the mass beween 5,000 and 15,000 tons. Raising the 15,000 tons to 25,000 tons would permit the assumption of a very flat object.

University of Iowa, January 25, 1943.

Contributions of the Society for Research on Meteorites

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Statistical Studies of the Meteoritic Falls of the World: 5. The Observed Sideritic and Siderolitic Falls[1]

By FREDERICK C. LEONARD
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ABSTRACT

This paper consists essentially of 3 tables: Table 1, 38 sideritic and siderolitic falls, of which the observation appears to be authentic; Table 2, 18 such falls, whose observation is doubtful or improbable; and Table 3, 7 such falls, so recently reported to have been witnessed as to call for further information, either to confirm or to disprove their reputed observation. The falls, especially those of Table 1, are briefly discussed, and the article ends with a recital of the criteria that may be used to determine whether or not a meteorite—iron or stone—was seen to fall.

So few siderites and siderolites have been observed to fall that a complete record of the few that have been either actually or allegedly witnessed would be of value. An attempt has been made in this paper to assemble such an enumeration, in the form of 3 tables, *to wit:* Table 1, falls of which the observation appears to be quite or practically beyond question; Table 2, falls whose observation is in each case extremely doubtful if not highly improbable; and Table 3, falls so recently reported to have been witnessed as to require further investigation for confirmation or disproof of their reputed observation. The material for this study has been derived from several sources, of which the most up to date are: (1) Dr. A. L. Coulson's catalog[2]; (2) Mrs. Addie D. Nininger's catalogs[3]; and (3) our own manuscript catalog.[4] All of the falls listed in Tables 1 and 2 are included in Dr. Coulson's catalog, while those appearing in Table 3 are to be found only in Mrs. Nininger's third and latest catalog and in the manuscript catalog. Altho the information contained in the following tables is as complete and correct

as the writer can at present make it, he cannot hope that it is free from mistakes, as far even as it goes; hence, he will be grateful to be advised of any errors "of omission or commission" that may be detected.

In the first column of each of the 3 tables—in which the falls are arranged chronologically—is given, for every fall, its common geographic name; in the second, its coördinate number or numerical designation[5] (if the location of the fall is known only approximately, this number is followed by a ± sign); in the third, its classification[6] (as precise as this has been published); in the fourth, its total weight in kilograms; in the fifth, the number of masses known to have been recovered from it; and in the sixth and last, the time of fall, or remarks pertaining to the reported time of fall, find, *etc.*, or the reported time of fall, as labeled in the particular table. The siderolitic falls are starred, and the following abbreviations are used in the tables: cl. = classification; fd. = found; fl. = fell; id. = identical; men. = mentioned; poss. = possibly; prob. = probably; pvd. = preserved; rcg. = recognized; rcv. = recovered; and unkn. = unknown.

The information for a number of the falls is obviously fragmentary and that for several is unavoidably inaccurate. If any of the missing facts can be ascertained and are supplied, they will constitute an invaluable accession to our knowledge of some of the most interesting falls on Earth. The primary purpose of this paper is to put on record, in one place, all of the falls enumerated in the accompanying tables, in the hope of stimulating further research in every case in which need for it is indicated.

The 38 falls of Table 1 are the only ones studied in this paper, of which the observation seems to be fairly certain, if it is not entirely so.[7] Of these 38, 28 are sideritic and 10 are siderolitic. Since there are on record about 8½ times as many sideritic falls as siderolitic, the ratio of the number of *observed* siderolitic falls to the *total* number of such falls known is 18⅓%, while the corresponding ratio for the sideritic falls is only 7⅓%; on the other hand, the analogous ratio for the aerolitic falls runs as high as 71%.[8] Inasmuch as the siderolitic falls are intermediate in nature between the sideritic and the aerolitic, it is to be expected that the *percentage* of the observed siderolitic falls would be higher than that of the observed sideritic falls. The extreme scarcity of the observed sideritic and siderolitic falls is manifest, however, from the statement that, for the whole continent of North America, only 6 falls of the former kind and but one of the latter have been reported up to date.

It is worthy of note that these 38 falls range in weight from less than one kilogram to more than 18,000 kg. (as estimated), in the case of the Bezerros, Brazil, iron, and to "probably as much as several thousands of metric tons," in the instance of the great central Siberian fall of the Podkamennaya Tunguska River (*v.* the note following Table 1), which occurred undoubtedly as a very extensive shower. A large majority (nearly 30) of the falls were single masses, while 6 consisted of from 2 to 5 members each; on the other hand, Estherville, Iowa, a mesosiderite (M), and Lowicz, Poland, a grahamite (Mg), were showers composed of numerous individuals (upwards of several dozens), as was also, in all likelihood—as has just been remarked—Podkamennaya Tunguska River, a siderite (Si). It is hardly necessary to add that the number of masses listed is in each case the number actually *recovered* from the fall named and so can represent only a *lower limit* to the *total* number of members belonging to it, and that a similar comment would apply to the assigned weight.

TABLE 1

TABLE 1

SIDERITIC AND SIDEROLITIC FALLS: OBSERVATION APPARENTLY AUTHENTIC

Geog. Name	Coörd. No.	Cl.	Total Wt. in Kg.	No. of Masses	Time of Fall
Hraschina, Zagreb, Croatia, Jugoslavia	*0160*,458	Om	49	2	1751 May 26, 6 P.M.
Charlotte, Dickson Co., Tenn.	0873,362	Of	4.3	1	1835 July 31 or Aug. 1, 2-3 P.M.
*Barea, Logrono, Spain	0024,424	M	3.2	1	1842 July 4
Braunau, Trutnov, Bohemia, Czechoslovakia	*0159*,505	Hn	39	2	1847 July 14, 3:45 A.M.
Victoria W., Cape Prov., Un. of S. Africa	*0222,318*	Ofv	3	1	1860
*Lodran, Multan Dist., Punjab, India	*0718*,295	Lo	1± (pvd.)	1	1868 Oct. 1, 2 P.M.
Nedagolla, Vizagapatam Dist., Madras, India	*0835*,187	Dn	4.5	1	1870 Jan. 23, 7 P.M.
Rowton, Wellington, Shropshire, England	0024,527	Om	3.4	1	1876 Apr. 20, 3:45 P.M.
*Estherville, Emmet Co., Ia.	0948,434	M	337	Many	1879 May 10, 5 P.M.
*Veramin, Karand, Teheran, Persia	*0517*,357	M	54	1	1880 May, "3^h before sunset."
Winburg, Orange Free State, Un. of S. Africa	*0274,283*	Om	50	1	1881
Mazapil, Zacatecas, Mexico	1014,248	Om	4	1	1885 Nov. 27, 9 P.M.
Cabin Creek, Johnson Co., Ark.	0933,354	Om	48.7	1	1886 Mar. 27, 3 P.M.
Hassi Jekna, Oued Mequiden, El Golea, S. Algeria	*0041*,335	Of	1.25	1	"Some years before 1890."
Quesa, Enguera, Valencia, Spain	0007,390	Of	10.75	1	1898 Aug. 1, 9 P.M.
N'Goureyma, Jenne, Massina, French W. Africa	0115,132	Obzg	37.5	1	1900 June 15
*Marjalahti, Viborg, Finland	*0287*,616	Pi	45	1	1902 June 1, 10 P.M.
Okano, Sasayama, Tamba, Japan	*1353*,349±	Hn	4.742	1	1904 Apr. 7, 6:35 A.M.
Pfullingen, Tübingen, Wurtemberg, Germany	*0090*,485	O	7.5	1	1904 Oct. 29, 4:00 P.M.
Avče, Isonzo Valley, Gorizia, Italy	*0137*,459	Hn	1.23	1	1908 Mar. 31, 8:45 A.M.
Podkamennaya Tunguska River, Yeniseisk, Siberia, U.S.S.R.[1]	*1019*,609	Si	Unkn.; not rcv.; r. n. (1).	Unkn.	1908 June 30, 7:00 A.M.
N'Kandhla, Zululand, Natal, Un. of S. Africa	*0318,273*	Om	17.3	1	1912 Aug. 1, 1:30 P.M.
Bezerros, Pernambuco, Brazil	0350,*090*	Si	18,180±	1	1915 May 9
Treysa, Hesse, Germany	*0096*,507	Om	63	1	1916 Apr. 3, 3:30 P.M.
Boguslavka, 220 km. N. of Vladivostok Siberia, U.S.S.R.	*1312*,465	Hn	256	2	1916 Oct. 18, 11:47 A.M.
Garhi Yasin, Shikarpur taluq, Sukkur Dist., S. India	*0685*,279	Om-Og	0.380	1	1917 Jan 7-15, "night-time."
Norfork, Baxter Co., Ark.	0923,362	Om	1.050	1	1918 Oct., "night."
Pitts, Wilcox Co., Ga.	0836,319	Ob	3.7	4	1921 Apr. 20, 9 A.M.

TABLE 1—(CONTINUED)

GEOG. NAME	COÖRD. NO.	CL.	TOTAL WT. IN KG.	NO. OF MASSES	TIME OF FALL
Samelia, Shahpura State, Rajputana, India	*0749*,257	Og	2.461	3	1921 May 20, 5:30 P.M.
Newtown, Fairfield Co., Ct.	0733,414	D	0.2156	1	1925 Dec. 29, 5 P.M.
*Udei Sta., Benue, N. Prov., Nigeria	*0100*,082±	P (or M?)	102.6	1?	1927 Mar. or Apr.
*Dyarrl Is., near New Ireland, New Guinea	*1503,003*±	Mg (or P?)	0.170(rcv.)	1?	1933 Jan. 31, 4:30 P.M.
Repeev Khutor, Lower Volga Dist., Russia, U.S.S.R.	*0469*,508±	O	7	1	1933 Aug. 8, 8 P.M.
*La Rinconda, Sevilla, Spain	0060,374	P?	0.008 (!)	1	1934 July 17
Bahjoi, Moradabad Dist., United Prov., India	*0785*,285	Og	10.32	1	1934 July 23, 9:30 P.M.
*Lowicz, Warsaw Dist., Poland	*0300*,521	Mg	59	58	1935 Mar. 12, 12:52 A.M.
Mallorca, Majorca, Balearic Is., Spain	*0027*,396±	O	0.809	1	1935 July 17, 11:35 A.M.
*Patwar, Tippera Dist., Bengal, India	*0912*,232	Mg	37.35	5	1935 July 29, 2:20 P.M.

NOTE TO TABLE 1

[1] This is the famous fall of central Siberia, from which no material has been recovered, at least by any man of science. "We estimate that the whole mass of the original iron meteorite, before its encounter with the Earth's atmosphere, was probably as much as several thousands of metric tons, but hardly as much as several tens of thousands" (L. A. Kulik, *C.S.R.M.*, **1**, No. 3, 62; *P. A.*, **45**, 562, 1937).

TABLE 2

SIDERITIC AND SIDEROLITIC FALLS: OBSERVATION DOUBTFUL OR IMPROBABLE

GEOG. NAME	COÖRD. NO.	CL.	TOTAL WT. IN KG.	NO. OF MASSES	REMARKS
Elbogen, Bohemia, Czechoslovakia	*0161*,506	Om	107	1	Fl.? 1400; men. 1785; rcg. 1811.
Jalandhar Dist., Punjab, India	*0759*,312	Si or So?	1.967	1	"Fl. 1621 Apr. 10"; not pvd.
Bohumilitz, Vimperk, Bohemia, Czechoslovakia	*0138*,491	Og	57	1	Fl.? 1770 Jan. 1; fd. 1829.
Piedade do Bagre, Minas Geraes, Brazil	0450,*182*	Om	?	1?	Fl.? 1833 Apr. 11, 6:45 P.M.; fd. 1922.
Deep Springs, Rockingham Co., N. C.	0796,363	Db	11.5	1	Fd., "said to have fallen," 1846.
Fukue, Goto Is., Nagasaki Pref., Kyushu, Japan	*1285*,328	Si: O?	?	?	Fl.? 1849 Jan.-Feb.; fd. 1842, according to I. S. Astapowitsch.
Jefferson, "30 mi. from Denver, Colo."	1053,396±	Si	0.041	1	Fl.? 1867 June; poss. id. with no. 1053,-396, Bear Creek, Jefferson Co., Colo. (Of), 227 kg., 1 mass, fd. 1866. G. T. Prior refers to Jefferson as "this doubtful iron."
*Calderilla, Caldera, Atacama, Chile	0708,*272*	P	0.021 (!)	1	Fl.? 1883. "A fragment."

					T. Prior refers to Jefferson as "this doubtful iron."
*Calderilla, Caldera, Atacama, Chile	0708,*272*	P	0.021 (!)	1	Fl.? 1883. "A fragment."

TABLE 2—(CONTINUED)

GEOG. NAME	COÖRD. NO.	CL.	TOTAL WT. IN KG.	NO. OF MASSES	REMARKS
Duchesne, Duchesne Co., Utah	1104,402	Of	22.8	1	Fl.? 1896 July 5; fd. 1906.
Mariaville, Rock Co., Neb.	0994,427	Si	0.340	1	Fl.? 1898 Oct. 16 midn.-Oct. 17, 1 A.M.; *v.* H. H. Nininger, *C.S.R.M.*, **1**, No. 3, 62-6; *P. A.*, **45**, 562-7, 1937.
Alwal, near Hyderabad, Hyderabad State, India	*0785*,174	Si?	"Size of tennis ball"	1	"Fl. about 1901, just before dawn"; not pvd.; *v.* M. A. R. Khan, *C.S.R.M.*, **1**, No. 2, 57-60; *P. A.*, **44**, 565-8, 1936. Cl. doubtful.
Hualpai (= Wallapai) Indian Reservation, Mohave Co., Ariz.	1137,354	Of	424	2	Fd. 1927; "fl. perhaps 1904-05, 4:30-5 P.M." (!).
Mejillones No. 2, Atacama, Chile	0707,*232*B	Dn	14.5	1	"Fd. 1905 May; label stated fl."; poss. id. with Mejillones No. 1 (Hb), fd. before 1875.
Norfolk, Montgomery Co., Va.	0763,369	Om	23	1	Fl.?1906 or 1907 Sep.; fd. 1906; *v.* H. H. Nininger, *l.c., under Mariaville, ante.*
Seneca Twp., Lenawee Co., Mich.	0842,418	Om	11.5	1	"Poss. fl. 1914"; fd. 1923 July.
Washington Co., Colo.	1032,402	D_1	?	1?	Fd. 1926; "prob. fl. 1916."
Santa Luzia de Goyaz, Goyaz, Brazil	0475,*162*	Ogg	4.5	1	Fd. 1921; "supposed to have fallen 1919 June 1, 6 P.M."
Gundaring, Western Australia	Unkn.	Og-Ogg	112.5	1	Fl.? 1930 Apr. 6, 2 P.M.; fd. 1937 May (Coulson); 1927 (A. D. Nininger).

TABLE 3

SIDERITIC AND SIDEROLITIC FALLS: RECENTLY REPORTED TO HAVE BEEN OBSERVED

GEOG. NAME	COÖRD. NO.	CL.	TOTAL WT. IN KG.	NO. OF MASSES	REPORTED TIME OF FALL
Hukuye, Gotô, Nagasaki, Japan	*1299*,331	Si	0.008 (!)	1	1842 Feb.
Magnesia, Asiatic Turkey	*0273*,375	Si	5	1	1899
Tyumen, West Siberia, U.S.S.R.	*0655*,572	Si	0.75	1	1903 Apr.
*Kizima, Simotakai, Nagano, Japan	*1376*,367	P?	0.331	2	1906 June 15
Rembang, Java	*1111*,071	Si	10	1	1919 Aug. 30
*Nanseiseki, Shantung, China	*1170*,368±	P	Unkn.	1?	1920 Aug. 13
Novorybinskoe, Stalin Dist., N. Kazakhstan, Siberia, U.S.S.R.	*0712*,519	O	3.055	1?	Prob. 1927

In the considered opinion of the writer, *probably not one* of the 18 falls of Table 2 was really observed; almost all of the available evidence points unequivocally to the conclusion that none of these falls was witnessed and that, accordingly, they were, in practically every case, recovered after—doubtless long after—their arrival on the planet.

Regarding the 7 falls of Table 3—which date from 1842 to 1927—all that can be said is what in effect has already been stated, namely, that they have so lately been reported to have been witnessed that confirmation or refutation is in each instance impossible and will continue to be so until such time as a definitive investigation of the fall has been made. Of the 63 falls considered in this paper, these last 7 are obviously most urgently in need of study, mainly to settle, once and for all time, the question of their alleged observation. It is of course reasonable to assume that some, if not all, of these falls were witnessed, but which ones were, if any, cannot be determined without careful inquiry into the circumstances of their discovery. Evidently, in view of the improbability or the indeterminateness of their observational status, no real purpose would here be served by a more extended discussion of the falls of either Table 2 or Table 3.

In conclusion, the writer cannot do better than to quote the very apt remarks of Dr. H. H. Nininger (who proved that the Norfork, Arkansas, siderite was a witnessed fall[9]), concerning the criteria or the *prima facie* evidence that may be employed to decide whether or not a meteorite—iron or stone—was observed to fall:

"The writer has collected many meteorites, and seldom has the finder failed to report that he had seen his specimen fall, in spite of the fact that most of these finds bear in themselves sufficient evidence of a considerable period of weathering. Meteorites have been falling upon the Earth doubtless throughout all geologic time. The finding of those which have lain on the Earth for some years is much more likely to happen than is the finding of a freshly fallen specimen. Before recording a meteorite as a witnessed fall, conclusive evidence should be obtained from persons who have actually seen its impact with the soil, or through such evidence as:

"*(a) Freshly disturbed* soil, vegetation, or other surface objects;

"*(b)* A *careful survey* of reported aërial phenomena, which should indicate the *site* of the find;

"*(c)* In every case, *evidence in the specimen itself,* which should be indicative of its *recent arrival* on the Earth.

"Meteorites arrive from a region where oxygen is scarce or absent. Consequently, the condition of their mineral constituents is noticeably different from that which characterizes terrestrial metals and rocks. In addition to this fact, meteorites undergo, during their plunge through our atmosphere, a treatment not accorded to any terrestrial object. Therefore, a careful examination of a specimen by one familiar with these bodies will enable him to determine within rather narrow limits the amount of weathering to which it has been exposed. *By far the most important testimony as to the approximate terrestrial age of a fallen meteorite must come always from a study of the meteorite itself.*"[10]

NOTES

[1] "Studies: 4. Their Classificational Distribution" appeared in *C.S.R.M., P.A.,* **51**, 44-9, 1943.

[2] *Mem. Geol. Surv. India,* **75**, 346 pp. *&c.*, 1940.

[3] *C.S.R.M.*, **1**, No. 3, 41-5, 1937; **2**, 96-101, 227-32, 1938-41; *P. A.*, **45**, 449-54, 1937; **47**, 209-14, 1939; **48**, 555-60, 1940.

[4] *C.S.R.M.*, **2**, 250, 1938-41; *P. A.*, **49**, 151, 1941.

[5] *C.S.R.M.*, **2**, 270, 1938-41; *P. A.*, **49**, 214-15, 1941.

[6] See, *e.g.*, the paper referred to in *n.* (1), *ante.*

[7] Some of even these falls, however, especially the last 9, which date from 1925 to 1935, ought to be further investigated.

[8] *Cf.* Table 3, *C.S.R.M.*, **2**, 255, 1938-41; *P. A.*, **49**, 156-7, 1941; see also Table 2, pp. 48-9, in the paper mentioned in *n.* (1), *ante.*

[9] *C.S.R.M.*, **1**, No. 3, 62-6, 1937; *P. A.*, **45**, 562-7, 1937.

[10] The italicizing of this final sentence is due to the present writer.

Death of the Discoverer of the Willamette, Oregon, Siderite

I have just verified a report, first heard about Christmas time, that Ellis Hughes, the discoverer of the Willamette, Oregon, meteorite (coördinate number = 1226,454), died and was buried at Oregon City, Oregon (just across the river from the point of discovery), early in December, 1942. He was 83. A group from here visited him and the place of discovery and other "old-timers" in the summer of 1938. The old man then seemed to be quite active physically and mentally but he was still very bitter over the court decision. He talked at length on his discovery but said, "There is no justice in the courts!" I have an excellent picture of him taken at that time. He was then living alone in a very humble dwelling in the country near the place of the find.

This 15¾-ton iron, which is by far the largest meteorite on record for the entire United States, is, and has been, since 1906, on exhibition in the American Museum of Natural History in New York City. For further details the reader is referred to the account of "The Willamette, Oregon, Meteorite in History," which appeared in *C.S.R.M.*, **2**, 85-7, 1938-41; *P. A.*, **47**, 148-50, 1939.

J. Hugh Pruett

University of Oregon, Eugene, 1943 January 20

Addendum.—Since writing the preceding, I have learned more from 3 different sources: 2 were newspaper men and the other the granddaughter of Mr. Hughes, who is in school here. Her mother in Portland had received a request for more information, had sent the letter here, and had asked the daughter to telephone me, as she did, last night.

Mr. Hughes died at his long-time home at Willamette on December 3, 1942, and was buried from Oregon City, across the river from Willamette, on December 5. He seemed in good health until a few minutes before his sudden death. He had just returned from a store.

Nininger (*Our Stone-Pelted Planet*, p. 161, 1933) gives the mass of the Willamette meteorite as 27,000 lbs., but several years ago the American Museum of Natural History wrote me that the weight is 31;535 lbs. This is the weight appearing also on the label of the "life-size" plaster model of the specimen here at the University of Oregon; so I think that it is correct.

J.H.P.

1943 January 28

"The Origin of the Carolina Bays" (Book)

"The Origin of the Carolina Bays" *(Columbia Geomorphic Studies, No. 4)*, by Douglas Johnson, Professor of Geology, Columbia University, xiii + 341 pp.,

published by the Columbia University Press, New York City, October, 1942, price $4.50. Following is the publisher's statement concerning this work:

"The Atlantic coastal plain in North and South Carolina is literally peppered with curious craters. The discovery was first made at the end of the 19th century, and various hypotheses have been offered as to the cause of them. Within the last 10 years, however, interest in these new land forms has increased tremendously, chiefly on account of the fact that aërial photographs have revealed hundreds of these craters where topographic maps have shown but 1 or 2. It is believed that there are literally hundreds of thousands of these craters in this particular area.

"The most spectacular, or at least the most highly publicized, theory of their origin has to do with meteorites, and this despite the fact that the area of most abundant meteorites is considerably west of the coastal plain. These craters are, in the main, elliptical or ovoid. Their axial relationships are uniform enough to be significant. All in all, the theory has been accepted popularly that these were caused by a hailstorm of meteorites that struck the Earth at an angle.

"The author of this book, however, offers a new hypothesis, and one that must be considered in its entirety before it can be dismissed or before any other hypothesis can be accepted."

The book has been briefly reviewed by Lewis G. Westgate of Ohio Wesleyan University in *Sky and Telescope*, **2**, No. 4, 16, February, 1943.

Notes from Amateurs

Jupiter by Day

During the last three months of 1942 my wife and I frequently observed Jupiter with the unaided eye shortly after sunrise. It being our habit to rise early on Sunday mornings to watch the stars and take an early stroll or swim along Galveston's beach we were thus afforded the unusual pleasure of observing Jupiter under these difficult conditions. We made similar observations on week-day mornings whenever the time allowed.

Our first observation came on Sunday, October 4, when the crescent of the old Moon stood nearby to serve as a guide for locating the planet. At that time we watched Jupiter until the apparent position of the Sun was four or five degrees above the horizon. Believing the observation impossible without such a guide we made no further attempts to see Jupiter after sunrise until November when we found that by getting our bearings earlier we could continue to find the planet after sun-up. By eight o'clock in the morning Jupiter had now passed the zenith; and, since this position was more favorable, the observations began to be considered quite commonplace. We continued our observing until by Christmas the planet had moved too far westward to shine after sunrise. Though many more observations were made, the following ones were recorded:

Date	Time of Sunrise	Last observed Jupiter
Sunday, October 4		Sun 4° above horizon
Friday, November 13	7:43 A.M.	7:55 A.M.
Sunday, November 15		Sun 8° above horizon
Sunday, December 13		After sunrise
Wednesday, December 16	8:07 A.M.	8:14 A.M.
Tuesday, December 22	8:09 A.M.	8:18 A.M.

NATHANAEL RATHBONE.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

A Memorial to Miss Vera M. Gushee

A poet who, like his greater brother, Lord Alfred Tennyson, sweeps the night skies with a two-inch telescope, wonders if teachers of astronomy fully realize their spiritual contributions to their students. During my years at Harvard University I was denied—because of a conflict of hours—the joy of studying astronomy and so, in later years, I returned to sit at the feet of Vera M. Gushee, who had come from Smith College to give a brief University Extension Course in Astronomy. Writing a letter of appreciation to my teacher and enclosing "Motes and Starbeams," which I had written after looking at the Orion Nebula for the first time, I received (January 27, 1933) a charming letter, in which the modest little lady wrote: "I meant to say before now (since you attached the letters Ph.D. to my name) that I have never worked for a Doctorate. The efforts I have made deliberately are towards a greater broadening of my intellectual background than I could get by aiming toward a Ph.D. in Astronomy." And then followed this significant conclusion: "My study at present is under the direction of Dr. Sarton at Harvard and I plan to attend his History of Science lectures this second semester. His little book, "History of Science and the New Humanism," appeals to me very much and I should like to devote the remainder of my teaching career to upholding the ideals he sets forth so clearly in those pages." Her life was the personification of Humanism: her radiant spirit was like a shining star and continues to inspire all who knew—and loved her.

Motes and Starbeams

My teacher was a woman, small of stature,
Yet tall enough of mind to touch the stars
With the help of a nine-inch equatorial telescope
And two steps of an observation rack.
When I had cracked the ponderous dome ajar
Enough to slice an area of sky,
She swung the telescope from north to east
Until Orion, bearing a shield of silver
And brandishing his club among the stars,
Strode titanically across the circled field.

"Look!" she said, switching in the clock
That keeps a telescope in step with stars,
"There's what you've waited forty years to see."

My eye followed up the velvet tube
To Orion's sword—no longer sword but stars
Palpitating in a cloud of green

Like sapphires shimmering in a gossamer veil.
"Wonderful!" I cried across the miles
Which light traverses in six hundred years
From Theta Orionis whose fire-tangled suns
Reveal, but do not pierce, the horseshoe cloud
Whose cosmic dust obscures remoter suns.
I, a mote upon a sphere of matter,
Was witness to the glory of creation,
Which is not finished but forever new.
I thought of men who map the stars by billions
And probe their secrets with a spectroscope,
But who, by stealth or skill, can bind Orion
Or bring his fire home to keep forever
Under lock and key for observation?

Man is small in bulk and comprehension—
A mote with grace to know he does not know—
And yet he towers in his insignificance
Above Orion and his starry kin,
For mind encompasses sidereal structures
And plumbs the awesome depths of space and time.
Should some erratic stranger, sunward curving,
Add prematurity to ultimate doom
Man would face the final dissolution
Aware of death, yet eager, with precision,
To calculate the place in space, and moment,
When he, the thinker, shall return the dust
Which he has borrowed from a perishing Earth.
The days and years which span man's understanding
Are less than seconds on the clock of time
But deep within the nucleus of matter
That forms the sensate mote which is a man
Stirs something less material than matter
And conscious of its difference from a star:
Aware of ordered beauty, glad to be
A living micron of eternity.

—HARRY ELMORE HURD.

Additional Note on the Origin of Loess

1. *Previous Notes*—My "Note on the Origin of Loess," published in POPULAR ASTRONOMY in August-September, 1931, introduced a meteoritic hypothesis as to the origin of loess. My other note, "The Break-up of Meteors," in the June-July, 1932, issue of POPULAR ASTRONOMY had in mind primarily the accounting for the sharply angular splinters of loess. In addition a short article on "The Distribution of Meteorites" (to be published later) has been prepared by me because of its bearing on the distribution of loess.

2. *The Sun, a Nova*—Some years ago I reached the conclusion that the Sun may have been a nova at the time of the last Ice Age. Both Shapley and Belot,

I later found, had anticipated my theory at least in part as to the nova stage of the Sun. Reasoning further, I concluded that the Sun may have thrown off so much material at the nova stage as to give rise to an important formation on the Earth; consequently I asked myself what geological formation is there that has never been satisfactorily explained; loess immediately suggested itself.

At the present time stony meteorites contain much silica in various compounds but, with a few exceptions, no quartz. If the material thrown off by the Sun experienced sudden congelation, this is to be expected; but on the other hand, if the material was enormously greater in amount, the silica might be metamorphosed into quartz if the temperature was maintained high enough for a sufficient period of time. If the temperature was maintained still higher, the silica might have become tridymite of which there has been one known sample among meteorites. At a still higher temperature cristobalite might have resulted, of which there is no known meteoritic example.

3. *Calcium Carbonate Tubes*—In a personal communication Dr. Rollin T. Chamberlin of the University of Chicago seemed to be in agreement with me that the vertical tubes of calcium carbonate in loess are probably due to the action of descending rain water. Let us remember, however, that chemical reactions in general are narrowly limited as to conditions permitting their occurrence. In the first place if the original material of loess contained carbonate of lime (calcium carbonate), rain water would not segregate it from the other material as carbonate of lime is relatively insoluble in water except when the water contains carbonic acid and in this case the end product would have been a bicarbonate instead of a carbonate. Instead of segregating the carbonate of lime the rain water would act to cement the whole mass together like the eolianites or eolian rocks of Bermuda.

Let us suppose that the original material of loess contained calcium oxide; in that case descending rain water would take the calcium oxide up in solution forming calcium hydroxide; this latter product readily absorbs carbon dioxide, which normally occurs in the air, whereupon the solution precipitates carbonate of lime. If the original material contained calcium oxide, then it could have been either volcanic material or meteoritic matter, since calcium oxide (unslacked lime) does not normally occur in earthy combinations except those that have been recently through a burning process. Lack of characteristic volcanic products seem to limit the material to a meteoritic origin. Meteorites, as is known, do contain calcium oxide in appreciable amounts.

4. *American Loess*—Dr. Chamberlin also called my attention to the fact that loess occurs about fifty feet thick near some of the large American rivers, as for instance the Missouri River near Council Bluffs, Iowa, but the formation thins out so that it almost vanishes thirty miles to the eastward. This condition is not consistent with an eolian hypothesis as to the origin of the formation. Wind action produces the thick part of its deposit on the lee side away from the source of the material, which in this case most geologists assume to be the glacial flood plain of the Missouri, just the opposite of what the conditions actually are.

On the other hand if the material was meteoritic in origin, it would still be subject to air currents in its descent to the Earth. At the higher altitudes the meteoritic material would drift from west to east under the influence of the Earth's rotation. In addition let us accept Hobb's theory of glacial anticyclones with special reference to the glacial flood plain of the Missouri in the present

problem. The anticyclone currents, where they operated in opposition to the direction of the west to east drift to the meteoritic material, would cause the material to be deposited in far greater amounts in a narrow zone on the eastern banks of the large American rivers, as is actually the case. It is also worth noting that the particles of loess are remarkably uniform in size and are coarser than the fine material of boulder clay or glacial till and fine rock flour such as would be present in glacial material collected by the wind from the flood plains of the large rivers.

5. *Test of Logic*—A rigorous application of logic leads to a break-down of the eolian hypothesis of the origin of loess, mainly due to the absence of trituration or rounded edges in the particles of loess although the lack of cross-bedding in loess also points in the same direction. Special emphasis should be placed upon accounting for the presence of calcium carbonate tubes in loess because of the limiting conditions it establishes upon a satisfactory explanation. Finally, there seems to be nothing really prohibitive to a meteoritic origin of loess, and if we stick to the inductive method the new explanation seems to be the more probable one.

JOHN B. PENNISTON.

General Notes

Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, received the doctorate of laws from Tufts College at the first mid-winter graduation ceremonies held on January 26. (*Science,* February 5, 1943)

Note on the Parallax of Canopus

By PETER VAN DE KAMP

In a recent article[1] in this Journal, Walkey erroneously refers to the distance of Canopus given in my list of first magnitude stars[2] as based on an old and admittedly uncertain spectrum measure. The absolute value of 0".033 ± .004 given by me is based on two spectroscopic values 0".038 (Adams)[3] and ".047 (Hoffleit),[4] and on the recent trigonometric photographic values of Johannesburg[5] +".005 ± .006 and Cape[6] +".028 ± .004, the latter value being derived from two accurate series of observations. With the value ".033 for the parallax the absolute magnitude of Canopus is —3.2, its luminosity 1900 times that of the Sun.

Sproul Observatory, Swarthmore, Pa., 1943, February 26.

[1] POPULAR ASTRONOMY **51**, 79, 1943.
[2] POPULAR ASTRONOMY **48**, 403, 1940.
[3] *Astroph. Jour.* **53**, 13, 1921.
[4] *Harvard Annals* **105**, 54, 1937.
[5] *Astr. Jour.* **47**, 81, 1938.
[6] *Month. Not.* **100**, 130, 1939.

Nicolas Copernicus Commemoration

One of the greatest scientific tributes in history is being planned throughout the United States for May 24, 1943, when hundreds of American universities, colleges, private schools, and technical institutions will join The Kosciuszko

Foundation in a nation-wide commemoration of the four-hundredth anniversary of the death of the "Father of Modern Astronomy," Nicolas Copernicus, Polish astronomical genius, and of the publication of his masterwork, "De Revolutionibus Orbium Coelestium," which proclaimed the heliocentric laws of the solar system and the mobility of the Earth through the heavens, thereby overturning the ancient geocentric system of Ptolemy of Alexandria and revolutionizing man's outlook upon the universe.

Dr. Henry Noble MacCracken, President of Vassar College and also President of The Kosciuszko Foundation, in announcing the plans for the commemoration said in part:

"On May 24, 1943, the world will celebrate the four-hundredth anniversary of the death of Nicolas Copernicus, the great Polish scientist. Today for the first time in 575 years, the alma mater of Copernicus, the University of Krakow, has been closed by the invader, the professors of that university imprisoned, thrown into a concentration camp. Two-fifths of them are understood to have lost their lives for the crime of being connected with the University of Copernicus. All the visible monuments of Polish civilization have been destroyed, but today Copernicus stands, the irrefutable answer to the invaders.

"The Kosciuszko Foundation, which since 1925 has endeavored to promote Polish culture, especially in the United States, urges you to consider at this time the possibility of featuring the four-hundredth anniversary of the death of Copernicus, because the modern period of science popularly dates from his death, because Poland is associated with the United States in the war of survival, and because the United States contains several million citizens of Polish extraction, who would be honored in the honor paid to their fellow countryman."

Federal Government Will Fill Technical and Scientific Aid Positions

Men and women are sought to fill positions as technical and scientific aid in the Federal Government. They are needed to do research and testing in the following fields: chemistry, geology, geophysics, mathematics, metallurgy, meteorology, physics, and radio. The positions pay $1,620 to $2,600, plus overtime.

Applicants may qualify through experience or education. For the assistant grade, applications will be accepted from persons who have completed 1 year of paid experience or a war training course approved by the U. S. Office of Education. One year of college study, including 1 course in the option applied for, is also qualifying. Persons now enrolled in war training or college courses may apply, subject to completion of the course. For the higher grade successively greater amounts of education or experience are required.

The majority of positions are in Washington, D. C., but some will be filled in other parts of the United States. There are no age limits, and no written test is required. Applications and complete information may be obtained from first-and second-class post offices, from civil service regional offices, and from the Commission in Washington, D. C. Applications will be accepted at the U. S. Civil Service Commission, Washington, D. C., until the needs at the service have been met.

Trainee positions in technical and scientific work will be filled in Washington, D. C., and vicinity. The salary is $1,440 a year plus overtime, and the only educational requirement is that the applicant must have completed one high school credit of physics, chemistry, mathematics, biology, or general science.

There are no options.

Persons using their highest skills in war work are not encouraged to apply. War Manpower restrictions on Federal appointments are given in Form 3989, posted in first- and second-class post offices.

UNITED STATES CIVIL SERVICE COMMISSION.

Economists and Statisticians Needed for Civilian War Service

Because of the urgent and continuing need for economists, economic analysts, and statisticians in the civilian war service, the Commission is intensifying its recruiting for these positions on a nation-wide basis. The positions pay $2,600 to $6,500 a year plus overtime, which increases salaries about 21% on the first $2,900 when the aggregate does not exceed $5,000 a year.

The greatest need is in the fields of transportation, labor, commodities, and industrial studies. Marketing, international trade, money and banking, and housing are also important fields for economist positions. Experience in other lines will also be utilized, and complete information may be obtained at first- and second-class post offices, from Civil Service Regional Offices, and from the U. S. Civil Service Commission at Washington, D. C.

Positions are both interesting and important to the war program. They include dealing with economic and statistical problems arising from the reoccupation of areas once held by the enemy, the sale of U. S. securities, exports and imports in connection with the war economic program, requirements for procurement of war materials, etc. Positions will be located throughout the United States, and a few will be filled abroad.

Requirements for the positions have been lowered. In general, only 5 years of college or university education or experience in economics or statistics, or a combination of the two, are necessary for the $2,600 grade. The minimum requirements for the higher grades are proportionately greater.

There are no age limits and no written examination will be given. Applications will be accepted until further notice, but qualified persons are asked to apply immediately. Applications are not desired from persons already using their highest skills in war work. War Manpower restrictions on Federal appointments are given in Form 3989, posted in first- and second-class post offices.

UNITED STATES CIVIL SERVICE COMMISSION.

613 G. Street, N.W., Washington, D. C.

A DRINK FROM THE LITTLE DIPPER

I can pluck the Little Dipper from the sky,
Unhook it from the place where it hangs high,
And take a drink,
A drink of water from a fairy spring,
So silver-voiced that it will make me sing
Of stars, I think.

And after I have sung these lovely songs,
I'll hang the Dipper up where it belongs
And drink the water from our kitchen sink.

—*By* CABOT BARBER,
Age 13.